I-105 GATEWAY CITIES

VIDEO DISTRIBUTION SYSTEM COMPONENT EVALUATION REPORT

Draft

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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

1 INTRODUCTION

The *Gateway Cities Traffic Signal Synchronization and Bus Speed Improvement Project* (or *The I-105 Corridor Project),* consists five major recommended components. One component, the Traveler Information and Surveillance System (TIASS), involves the ability for agencies to view and control cameras located throughout the corridor. The cameras are to be jointly operated by various agencies in the corridor regardless of geographic location. This requirement brings about the need to distribute video surveillance information to all agencies involved. This document provides an evaluation of video distribution options including possible system architectures and the available off-the-shelf solutions that best meet the needs of the I-105 Corridor agencies to realize this objective.

1.1 Purpose of the Document

The purpose of this document is to provide a comprehensive evaluation of the potential options for a video distribution system to collect CCTV surveillance images from signalized intersections and make them available to agency management centers within and outside the I-105 Corridor. This document is structured to provide the reader with background information on the particular requirements of the I-105 Corridor as well as available video system technologies. Then, various system architectures are presented to achieve the objectives of the video distribution system. An evaluation of current vendor's product offerings is discussed, and finally, a recommendation is provided that defines the architecture and potential off-the-shelf solutions. This report will provide the basis for the detailed design of the video distribution system.

1.2 References

This report was prepared using the following documents as reference materials:

- T*he Gateway Cities Traffic Signal Synchronization and Bus Speed Improvement Project (I-105 Corridor) – Conceptual Design document – Version 2.0*
- *The Gateway Cities Traffic Signal Synchronization and Bus Speed Improvement Project (I-105 Corridor) – Traveler Information Surveillance, Integration, and Communications System High Level Design Definitions and Recommendations – Version 2.0*
- T*he Gateway Cities Traffic Signal Synchronization and Bus Speed Improvement Project (I-105 Corridor) Functional Requirements – Version 1.3*

2 VIDEO DISTRIBUTION SYSTEM OVERVIEW

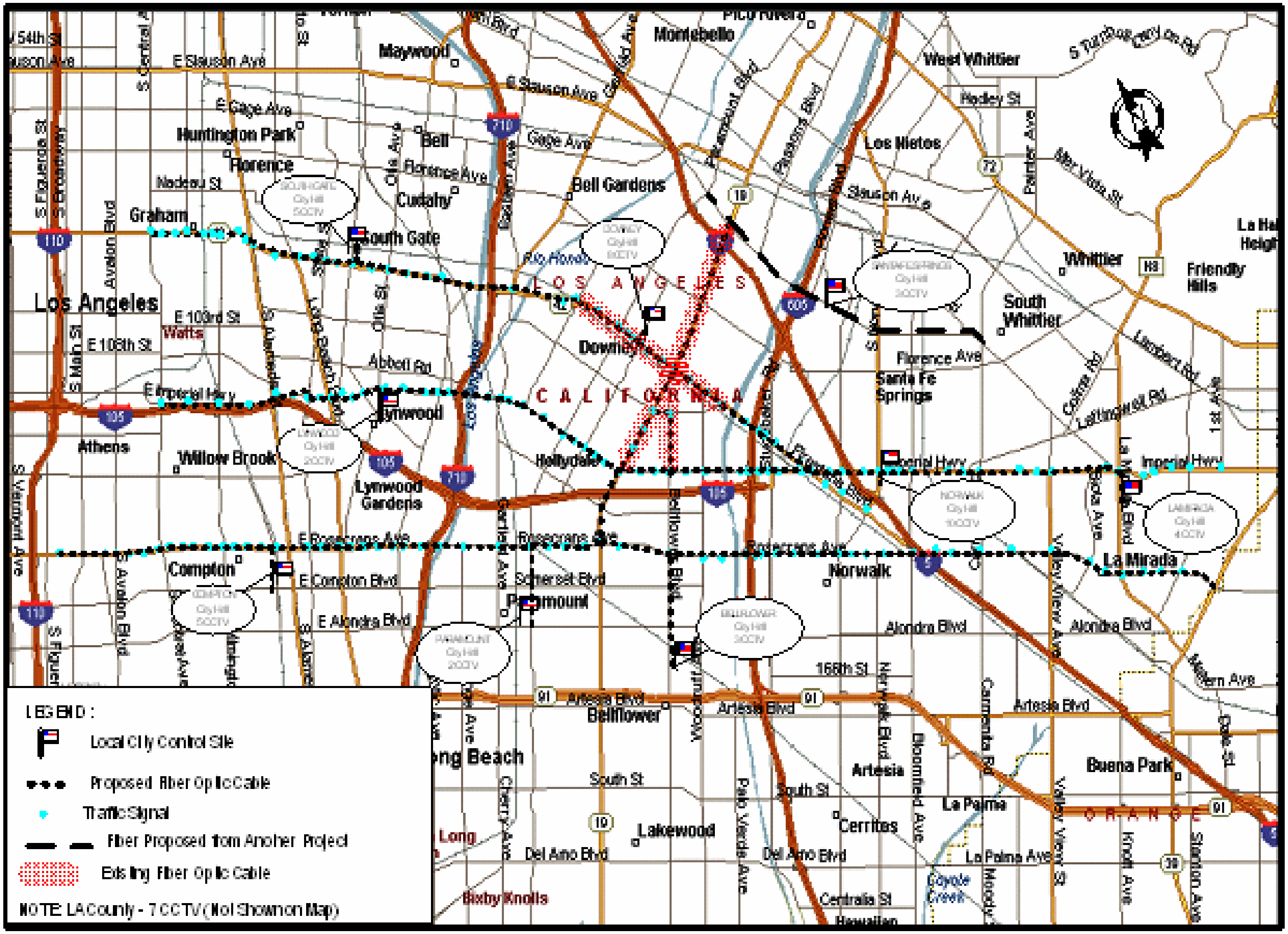
This section provides an overview of the video distribution system outlined in the I-105 Corridor Conceptual Design Report. This overview includes a description of the agencies that will share video images, locations of the CCTV cameras, and the anticipated communications technologies to be utilized for the transfer of video images and camera control commands.

2.1 I-105 Corridor Area

The I-105 Corridor project area, as shown in Figure 2-1, consists of Firestone Boulevard, Rosecrans Avenue, and Imperial Highway, which run parallel to I-105 freeway. There are also four arterials that run perpendicular to the I-105 freeway: Paramount Boulevard, Lakewood Boulevard, Bellflower Boulevard, and Studebaker Road. The arterials traverse nine municipalities and two regional jurisdictional boundaries. These agencies are listed as follows:

- City of Downey
- City of Norwalk
- City of South Gate
- City of Santa Fe Springs
- City of Bellflower
- City of Compton
- City of La Mirada
- City of Lynwood
- City of Paramount
- Los Angeles County
- Caltrans District 7

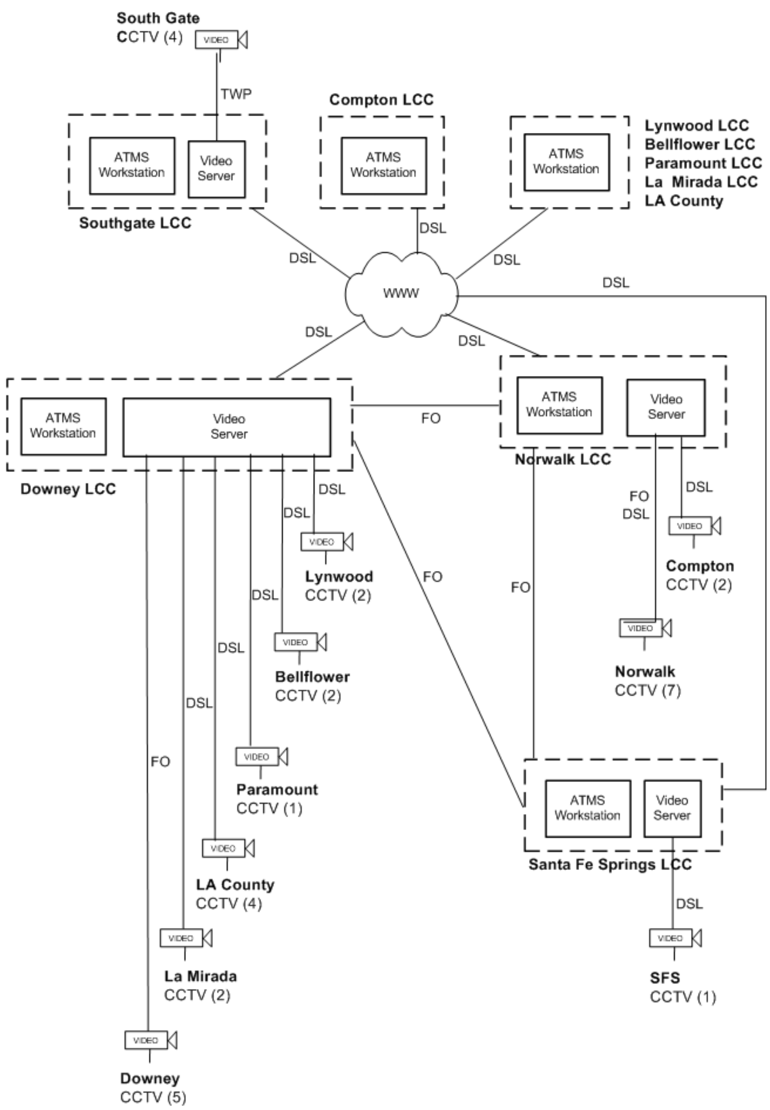
Figure 2-1: I-105 Corridor Area



2.2 Local Control Centers (LCC)

It is proposed that each agency have its own Local Control Center (LCC) to control and monitor ITS field equipment within each respective jurisdiction. It is also proposed that CCTV surveillance cameras be installed at signalized intersections along the previously mentioned arterials. Due to existing communications infrastructure limitations, some cities will control and monitor their field elements remotely via another agency's center. This is illustrated in Figure 2-2. It is desired that agencies in the corridor have the ability to share the viewing of surveillance images as well as pan-tilt-zoom control of these cameras. This will allow agencies to better coordinate traffic management along common arterials for both recurrent and non-recurrent traffic congestion.

Figure 2-2: i-105 Video Distribution System - Context Diagram



2.3 CCTV Cameras

There are a total of 30 CCTV cameras proposed for the I-105 Corridor area. Table 2-1 lists these cameras along the jurisdiction that each is to be located, the LCC designated to receive the video images, and the type of communications link between the LCC and each camera.

Table 2-1: Proposed CCTV Camera Inventory for I-105 Corridor Area

Jurisdiction	Qty	Location(s)	Communication Type	LCC
Downey	5	Firestone & Paramount Firestone & Lakewood Imperial & Paramount Imperial & Lakewood Imperial & Bellflower	Fiber Optic Cable Fiber Optic Cable Fiber Optic Cable Fiber Optic Cable Fiber Optic Cable	Downey
Norwalk	7	Firestone & Studebaker Firestone & Imperial Firestone & Pioneer Imperial & Bloomfield Rosecrans & Studebaker Rosecrans & Pioneer Rosecrans & Carmenita	Fiber Optic Cable Fiber Optic Cable DSL Fiber Optic Cable DSL DSL DSL	Norwalk
Santa Fe Springs	1	Rosecrans & Valley View	DSL	Santa Fe Springs
Paramount	1	Rosecrans & Paramount	DSL	Downey
Compton	2	Rosecrans & Wilmington Rosecrans & Long Beach Blvd	DSL DSL	Norwalk
Lynwood	2	Imperial & Long Beach Blvd Imperial & Atlantic Blvd	DSL DSL	Downey
La Mirada	2	Imperial & Valley View Rd Imperial & La Mirada Blvd	Fiber Fiber	Downey
South Gate	3	Firestone & Long Beach Blvd Firestone & Atlantic Ave Firestone & Garfield Ave Firestone & California Ave	TWP Cable TWP Cable TWP Cable TWP Cable	South Gate
Bellflower	2	Rosecrans & Lakewood Blvd Rosecrans & Woodruff Ave S	DSL DSL	Downey
LA County	4	Firestone & Compton Ave Imperial & Carmenita Rd Rosecrans & Avalon Blvd Rosecrans & Atlantic Blvd	DSL DSL DSL DSL	Downey

2.4 Communications Infrastructure for Video Transmission

The initial deployment of the communication system in the I-105 Corridor is proposed to compliment the already existing fiber and twisted-pair infrastructure. The existing and proposed cable system will connect 14 of the 30 proposed CCTV camera locations to LCCs, while 16 CCTV cameras will utilize leased communication lines for video transmission. These leased communications have been defined as high-speed Digital Subscriber Loop (DSL) service. Due to the fact that most cities require the use of DSL lines for video transmission, the number of LCCs receiving video images has been reduced. Only cities that plan to have cable systems are to receive video images. This approach reduces the number of video collection/distribution servers that are needed in the corridor.

The proposed initial deployment includes the installation of fiber optic cable along the following arterials:

- Imperial Highway from Garfield Avenue to Bellflower Blvd.;
- Imperial Highway from Firestone Blvd. to Carmenita Rd.; and
- Firestone Blvd. from Stewart and Gray Street to Imperial Highway.

The proposed initial deployment plans to leverage the City of Downey's existing and planned fiber optic cable within the following limits:

- Firestone Blvd. from Ryerson Ave. to Stewart & Gray Rd.;
- Lakewood Blvd. from Imperial Highway to Telegraph Rd.;
- Bellflower Blvd. from Imperial Highway to Stewart & Gray Rd.; and
- Stewart & Gray Rd. from Lakewood to Bellflower Blvd.

The City of South Gate has existing twisted-pair along Firestone Blvd. between Santa Fe Ave. and Ryerson Ave., which is proposed to be used as part of this initial deployment.

3 VIDEO DISTRIBUTION REQUIREMENTS AND DESIGN CONSTRAINTS

Selection of the appropriate video distribution system architecture is driven by two considerations: 1) the desired behavior of the system, referred to as the functional requirements of the system; and 2) the existing conditions that constrain the design. The latter is limited by the extent of the existing communications infrastructure and the budget available to expand the system. The functional requirements are synthesized into system requirements which define the characteristics of the system that must be implemented to achieve the desired functionality.

3.1 Functional Requirements

The following bulleted items have been taken from the Functional Requirements Document – Version 1.3, developed as part of the high-level design phase of the project.

- The Sub-Regional TMC shall operate cameras remotely for traffic surveillance (if in a staffed facility only; subject to policies).
- The LCC shall provide direct monitoring and control of traffic surveillance devices within the local jurisdiction including system detectors and CCTV.
- The LCC shall provide a windows-based graphical display for traffic surveillance.
- The LCC shall allow each city to choose an integrated user interface for system control, or maintain separate control of subsystems for traffic surveillance (i.e., dedicated monitor(s) for video and graphic display).
- CCTV cameras shall be capable of full-motion, color video.
- CCTV cameras shall include pan, tilt, and zoom (PTZ) capability.
- It shall be possible to share viewing of video images among jurisdictions in the I-105 Corridor.
- It shall be possible to share control of CCTV cameras among jurisdictions in the I-105 Corridor.
- The TIASS operator shall have the ability to select and input the content of the information including video feeds to be displayed on kiosks.
- The TIASS operator shall have the ability to select and input the content of the information including video feeds to be displayed on the web page.
- The CCTV system shall meet the National Television System Committee (NTSC) compliance for composite video output, geometric distortion, and aspect ratio.

3.2 Center-to-Center Communications Bandwidth Constraints

Choosing system architecture for video collection and distribution is constrained by the communication infrastructure which places limits on the amount of bandwidth available for video transmission from CCTV cameras to LCCs and between each LCC. Some agencies will have fiber optics and twisted-pair cable, while other agencies must depend on leased-line communications. Table 3-1 lists the proposed communications links to each LCC along with the associated bandwidth and the proposed number of simultaneous video streams to be transmitted and received at each LCC.

Table 3-1: Communications Bandwidth Constraints

AGENCY	FROM	TO	Communications Type	Bandwidth	Video Streams
City of Downey	Encoders	LCC	Fiber Optics	100 Mbps	5
	Encoders	LCC	DSL	(11) 384 kbps	11
	LCC	WAN	Leased	(7) 384 kbps	7
	LCC	WAN	Fiber Optics	1000 Mbps	4
	WAN	LCC	Leased	(1) 384 kbps	1
	WAN	LCC	Fiber Optics	1000 Mbps	4
City of Norwalk	Encoders	LCC	Fiber Optics	100 Mbps	3
	Encoders	LCC	DSL	(6) 384 kbps	6
	LCC	WAN	Leased	(7) 384 kbps	7
	LCC	WAN	Fiber Optics	1000 Mbps	4
	WAN	LCC	Leased	(1) 384 kbps	1
	WAN	LCC	Fiber Optics	1000 Mbps	4
City of Santa Fe Springs	Encoders	LCC	Fiber Optics	100 Mbps	?
	Encoders	LCC	DSL	(?) 384 kbps	?
	Encoders	LCC	Fiber Optics	100 Mbps	?
	LCC	WAN	Fiber Optics	1000 Mbps	4
	WAN	LCC	Leased	(1) 384 kbps	1
	WAN	LCC	Fiber Optics	1000 Mbps	4
City of South Gate	Encoders	LCC	Twisted-pair	Analog	4
	LCC	WAN	Leased	(9) 384 kbps	9
	WAN	LCC	Leased	(1) 384 kbps	1
City of Compton	WAN	LCC	Leased	(1) 384 kbps	1
City of La Mirada	WAN	LCC	Leased	(1) 384 kbps	1
City of Lynwood	WAN	LCC	Leased	(1) 384 kbps	1
City of Paramount	WAN	LCC	Leased	(1) 384 kbps	1
City of Bellflower	WAN	LCC	Leased	(1) 384 kbps	1
LA County	WAN	LCC	Leased	(1) 384 kbps	1

3.3 System Requirements

The system requirements, which are derived from the functional requirements listed previously, have been grouped into the three main components that comprise the video distribution system:

- Video Encoders
- Video Servers
- Video Management Software

These components are described in more detail in Section 4.

3.3.1 Video Encoders

- Video Encoders shall be able to compress analog video to suitable compression levels to allow transmission over high-bandwidth agency-owned communication links as well as low-bandwidth, leased-lines (e.g. 384 kbps).
- Video Encoders shall be compatible with the video server(s) employed to distribute the video streams.
- Video Encoders shall be capable of transporting camera control commands (i.e. pan, tilt, zoom, and focus) to the CCTV camera assembly.

3.3.2 Video Servers

- Video Server(s) employed shall be capable of accepting a minimum of 20 simultaneous video streams at a minimum of 384 kbps using standard video compression algorithms.
- Video Server(s) shall be able to distribute a total of 30 simultaneous video streams to other LCCs.
- Video Servers(s) shall allow an agency to select any of the 30 CCTV cameras to receive a video stream from the CCTV camera.
- Video Servers(s) shall allow an agency receiving a video stream from a CCTV camera to control the CCTV camera including pan, tilt, zoom, and focus.

3.3.3 Video Management Software

- Video Management Software shall provide a graphical user interface (GUI) to allow agency operators to select, view, and control a minimum of 30 CCTV cameras.
- Video Management Software shall decode video streams that are digitally compressed and display them in a window on the GUI.
- Video Management Software shall allow CCTV camera selection through a hypertext link to the streaming video source such as a Video Encoder.
- Video Management Software may be implemented using a commercial-off-the-shelf (COTS) software package that is compatible with the CCTV cameras, Video Encoders, and Video Server(s).
- Video Management Software may be implemented with different Commercial-Off-The Shelf (COTS) software packages for each LCC, as long as it is compatible with the CCTV cameras, Video Encoders, and Video Server(s).

- Video Management Software shall provide the ability for an agency to set user privileges to prioritize access to CCTV cameras in its jurisdiction by other agencies.

4 VIDEO TECHNOLOGIES

This section of the report will discuss the video technologies and techniques applicable to the I-105 Gateway Cities Project video distribution and control system. In the next section, evaluation of the germane technologies and techniques presented in this section will take place.

The video technology topic discussion will be separated as follows:

- Video Compression Technologies and Standards;
- Video Server Technologies;
- Video Distribution to the Desktop; and
- Centralized Video Software.

4.1 Video Compression Technologies and Standards

There are a number of different video compression techniques and standards applicable to the I-105 Corridor video distribution network. Some of these standards have been in existence for many years while others are relatively new and still merging. Some were developed for very specific uses and are therefore only applicable for certain applications. This section will present a foundation for selection of the most suitable video compression technology for this project.

The Problem:

1) A standard NTSC video	= 760x480 lines = 345,600 pixels
2) At 30 frames/second	= 10,368,000 pixels/second
3) 16 bits/pixel	= 165,888,000 bits/sec (uncompressed digital video)

Our available network bandwidths:

<u>LAN</u>

- Ethernet	= 10/100 Mbps

<u>WAN</u>

- ISDN	= 128 kbps
- T-1	= 1.5Mbps
- DS-3	= 45 Mbps
- OC-3	= 155 Mbps
- OC-12	= 622 Mbps

<u>Cellular</u>

- 1G	= 19.2 kbps (AMPS)
- 2G	= 56 kbps (GSM/CDMA/TDMA)
- 2.5G	= 180 kbps+ (GPRS/EDGE/CDMA2000)
- 3G	= 2.7 Mbps (WCDMA/CDMA2000)
- 4G	= 200+ Mbps (future)

Uncompressed digital video requires too much network bandwidth for multicast video distribution over standard networks

As depicted above, digital video compression must be used for effective distribution of video across networks, particularly when multicast (or multiple unicast) video is required, since existing networks are unable to support a flood of high-bandwidth uncompressed digital video.

<u>*Video Compression Methods*</u>

At its most basic level, compression is performed when an input video stream is analyzed and information that is indiscernible to the viewer is discarded. Each event is then assigned a code - commonly occurring events are assigned few bits and rare events will have codes or more bits. These steps are commonly called signal analysis, quantization and variable length encoding respectively. There are four methods for compression; Discrete Cosine Transform (DCT), Vector Quantization (VQ), Fractal Compression, and Discrete Wavelet Transform (DWT).

> *Discrete Cosine Transform* is a lossy compression algorithm that samples an image at regular intervals, analyzes the frequency components present in the sample, and discards those frequencies which do not affect the image as the human eye perceives it. DCT is the basis of standards such as JPEG, MPEG, H.261, and H.263.
>
> *Vector Quantization* is a lossy compression that looks at an array of data, instead of individual values. It can then generalize what it sees, compressing redundant data, while at the same time retaining the desired object or data stream's original intent.
>
> *Fractal Compression* is a form of VQ and is also a lossy compression. Compression is performed by locating self-similar sections of an image, then using a fractal algorithm to generate the sections.
>
> Like DCT, *Discrete Wavelet Transform* mathematically transforms an image into frequency components. The process is performed on the entire image, which differs from the other methods, such as the DCT, that work on smaller pieces of the desired data. The result is a hierarchical representation of an image, where each layer represents a frequency band.

4.1.1 Video Compression Standards

There are three (3) different standards bodies involved with developing video compression standards: 1) the Joint Photographic Experts Group (JPEG), an International Standards Organization (ISO) working group; 2) The Motion Pictures Experts Group, also an ISO working group; and 3) the Video Coding Experts Group (VCEG), an International Telecommunications Union (ITU) working group. The International Electrotechnical Commission (IEC) is also involved with these standards. Most of the MPEG standards are joint ISO/IEC efforts. Table 4-1 below summarizes the video compression standards governed by each, followed by brief descriptions of each of these standards plus some other relevant ones.

Table 4-1: Video Compression Standards Organizations

Standards Organization	Video Compression Standard
Joint Photographic Experts Group (JPEG) - ISO Working Group	JPEG MJPEG JPEG2000
Motion Pictures Experts Group - ISO Working Group	MPEG-1 MPEG-2 MPEG-4 MPEG-7 MPEG-21
International Telecommunications Union	H.261 H.262 H.263 H.263+ H.264 H.26L

Table 4-2 below lists and describes all of the video compression standards as well as a few non-standardized video compression techniques.

Table 4-2: Video Compression Standards and Techniques

JPEG	JPEG (Joint Photographic Experts Group) is an ISO/IEC group of experts that develops and maintains standards for a suite of compression algorithms for computer image files. JPEG (usually pronounced JAY-peg) defines any graphic image file produced by using a JPEG standard. A JPEG file is created by choosing from a range of compression qualities (actually, from one of a suite of compression algorithms). Together with the Graphic Interchange Format (GIF) and Portable Network Graphics (PNG) file formats, the JPEG is one of the image file formats supported on the World Wide Web. It defines video image captures for single still images.
MJPEG	MJPEG stands for "Motion JPEG" and is JPEG-based. MJPEG is identical to JPEG except that multiple captured still images are played together to form a motion image file. MJPEG is not the same as MPEG, although the names are confusingly similar. The primary difference is that MPEG provides temporal compression, while MJPEG only provides spatial compression.

JPEG2000	JPEG 2000 is an initiative that will provide an image coding system using compression techniques based on the use of wavelet technology. See description of Wavelets video compression below.
MPEG-1	MPEG stands for Motion Pictures Experts Group. MPEG-1 is the first internationally adopted digital video and audio encoding standard. It was adopted in 1992 as a means for encoding VHS quality digital video for CD-ROM playback. It was designed for providing digital video at optimal rates up to 1.5 Mbps for a 352 x 240 image at 30 frames per second. In addition, level 3 of MPEG-1 is the most popular standard for digital compression of audio--known as MP3. MPEG-1 is the standard of compression for VideoCD, the most popular video distribution format throughout much of Asia.
MPEG-2	This standard was originally developed for coding of broadcast television, but was expanded to encompass High Definition Television (HDTV). It became published as a standard in 1994 to support high bandwidth applications from 2 Mbps to 40 Mbps. It is backward compatible with MPEG-1 and was designed for flexibility and scalability, supporting many levels of service across a wide bandwidth range. The main difference between MPEG-1 and MPEG-2 is that MPEG-2 supports both progressive and interlaced framing. MPEG-1 only supports progressive. Original movie film and television broadcasts are progressive scan format. MPEG-2 is the current satellite TV, DVD and HDTV format.
MPEG-4	The MPEG-4 standard is the most recent encoding standard, which became usable in 1999. One of the main differences between MPEG-4 and MPEG-1 or MPEG-2 is that it has been designed for scalability from 64 kbps and higher up to 4Mbps. The low bandwidth capability makes it suitable for internet, videoconferencing and other lower bandwidth applications. MPEG-4 supports both interlaced and progressive scanning, but is more advanced as it goes beyond simple conversion and compression to include object recognition plus provisions for synchronized text and metadata tracks. The object-based compression codes multiple video object planes into arbitrary shapes. This enables scalability to provide higher compression for certain objects (such as backbround objects) and lower compression for foreground objects (such as an actor). MPEG4 supports a number of different subsets, called profiles, which identifies which tools an MPEG4 decoder supports. Two of the more common profiles are called Simple Profile and Advanced Simple Profile.
MPEG-7	This developing standard is also called the Multimedia Content Description Interface. When released, the group hopes the standard will provide a framework for multimedia content that will include information on content manipulation, filtering and personalization, as well as the integrity and security of the content. Contrary to the previous MPEG standards, which described actual content, MPEG-7 will represent information about the content.

MPEG-21	Work on this standard, also called the Multimedia Framework, is relatively recent. MPEG-21 will attempt to describe the elements needed to build an infrastructure for the delivery and consumption of multimedia content, and how they will relate to each other. MPEG-21 provides a larger, architectural framework for the creation and delivery of multimedia. It defines seven key elements: • Digital item declaration • Digital item identification and declaration • Content handling and usage • Intellectual property management and protection • Terminals and networks • Content representation • Event reporting
H.261	H.261 is an ITU standard designed initially for two-way communication over ISDN lines (video conferencing) and supports data rates which are multiples of 64Kbit/s. The algorithm is based on DCT and can be implemented in hardware or software and uses intraframe and interframe compression. H.261 supports Common Intermediate Format (CIF) and Quarter CIF resolutions. CIF represents a set of common video formats used for videoconferencing with full CIF representing a 352x288 image. Other formats include: QCIF is 176x144, Sub quarter CIF is 128x96, 4CIF is 704x576 and 16CIF is 1408x1152.
H.262	H.262 is identical to MPEG-2. Formally ISO/IEC 13818-2 & ITU-T H.262 standards developed in 1994 jointly by ITU-T and ISO/IEC.
H.263	H.263 is based on H.261 with enhancements that improve video quality over modems and typically transmits video at 176x144 pixels (QCIF). It also supports CIF, QCIF, SQCIF, 4CIF and 16CIF resolutions.
H.263+	H.263+ is an extension of H.263. It has several additional features and negotiable additional modes. It provides SNR scalability as well as spatial and temporal scalability. It has custom source formats. Advanced intra coding is used to improve the compression efficiency.
H.264/H.26L	H.264, or MPEG-4 Part 10, is a high compression digital video codec standard written by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/IEC Moving Picture Experts Group (MPEG) as the product of a collective partnership effort known as the Joint Video Team (JVT). The ITU-T H.264 standard and the ISO/IEC MPEG-4 Part 10 standard (formally, ISO/IEC 14496-10) are technically identical, and the technology is also known as AVC, for Advanced Video Coding. The final drafting work on the first version of the standard was completed in May of 2003.
Wavelets	Wavelets video compression techniques are based on Wavelet theory, which is also a form of mathematical transformation, in that it takes a signal in time domain, and represents it in frequency domain. Wavelets video compression delivers high-quality moving images by starting with

	still images, applying a compression method to them, and putting them together to form moving pictures. JPEG 2000 is a wavelets-based video compression algorithm.
DivX	DivX is a software application that uses the MPEG-4 standard to compress digital video, so it can be downloaded over a DSL/cable modem connection in a relatively short time with no reduced visual quality. The latest version of the codec, DivX 6, has been released by DivXNetworks and the open source community. DivX works on Windows 98, ME, 2000, CE, Mac and Linux.
DV	DV is a high-resolution digital video format used with video cameras and camcorders. The standard uses DCT to compress the pixel data and is a form of lossy compression. The resulting video stream is transferred from the recording device via FireWire (IEEE 1394), a high-speed serial bus capable of transferring data up to 50 MB/sec.

It should be noted that there are other proprietary video compression methodologies besides those identified in these standards (e.g. Real Networks, Microsoft, Quicktime, etc.)

4.2 Video Distribution to the Desktop

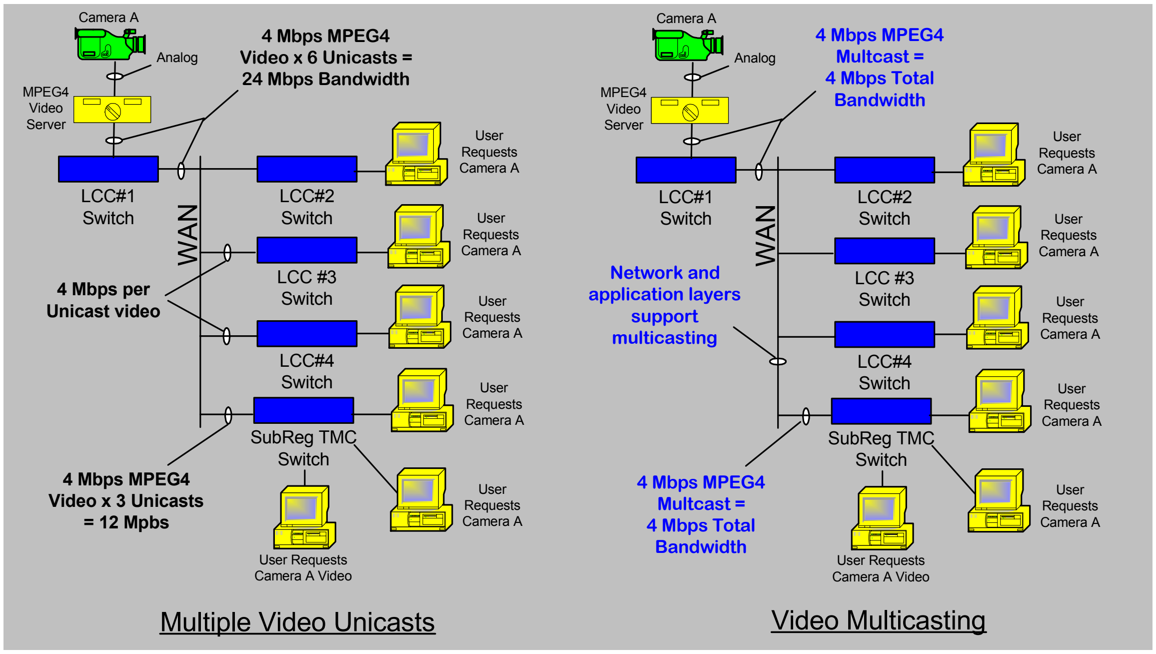
For a digital video distribution system, video is created, stored or buffered and then transported to the desktop for playback. A video server or servers must generally be deployed so the streaming images can be shared over the network, be it a private LAN, WAN or via the internet; although, the video serving function can also take place right at the camera itself. The server can act to provide real time broadcast, non-streamed downloading or streaming to the desktop. Real time broadcasting involves converting the analog video to digital on the fly and sending it to the desktop. Non-streamed downloading involves copying a stored streaming image from the server and playing it back on the end-user machine. Streaming to the desktop is simply "playing" a stored or buffered image on the server and sending video from the IP network to the users desktop where it is played using a desktop video viewer or plug-in (e.g. RealOne, Quicktime, etc.) or through other video viewing and control software. Since the I-105 Corridor project requires real time or near real time video viewing, only options that involved real time broadcasting or streaming will be considered here.

Video IP Multicasting vs. Unicasting

The I-105 Corridor video system requires the distribution of multiple video signals from the same source or sources to multiple possible destinations, i.e. the LCCs and Subregional TMC. Therefore, video must be sent in the form of multiple unicasts (one dedicated bandwidth stream for each video) or true IP multicast where the video servers and networking components enable group communications while persevering bandwidth in an efficient manner. With IP Multicast, one video can be sent to multiple destinations without causing unnecessary bandwidth usage or network bottlenecks. Figure 4-1 is a basic depiction of the difference between multiple video IP unicasting and video IP multicasting in the context of the I-105 Corridor project.

When discussing video multicasting, it is necessary to discuss that this can be accomplished at three different network layers: the application layer, the network layer and the physical layer.

Figure 4-1 – IP Multicast vs Multiple Unicasts



Application-Layer Multicast — In this case, all multicast support is provided at the application layer. By running distributed algorithms, receivers of a multicast session organize themselves in an overlay network. All communications are then carried out using unicast between neighbors of this overlay network. This offers the advantage of possible immediate deployment since it can utilize all the flow/congestion control capabilities available for unicast. The disadvantages are higher delays and inefficient use of bandwidth. Some packets may traverse the same link back and forth. Application-layer multicast is also referred to as overlay or end-systems multicast.

Network-Layer (IP) Multicast — Multicast routers are needed in this case. These routers are responsible for building and managing multicast distribution trees. At the routers, multicast packets are replicated and forwarded down to the multicast tree leaves. Multicast routers that are on a leaf network discover and communicate with local receivers of a multicast session. The Internet Group Management Protocol (IGMP) is used for this purpose. IP multicast is deployed in the experimental virtual network, the Multicast Backbone (MBONE). It is implemented using tunneling schemes between multicast routers on the Internet. These tunnels constitute a virtual network on top of the Internet.

Physical-Layer (Local-Area) Multicast — This type of multicast utilizes the broadcast capabilities of the underlying physical layer. An example of this is Ethernet. It is carried out by broadcasting the information to all receivers on the physical media. Receivers filter the traffic to get the information destined to them. This serves the purpose of distributing information locally in a LAN environment. There can also be a mapping between either application-layer multicast or IP multicast and physical-layer multicast.

Video Transport Protocols

Another key issue with network video distribution is the network protocol, of which there are many choices. Video transmitted via an Ethernet LAN or the internet must be transported within the IP architecture, which warrants the need for a reliable IP transport protocol, and in turn, the network which the video will ride upon must be designed and configured to support these protocols. There are several to choose from. They are:

- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)
- Real-Time Transport Protocol (RTP)
- Real-Time Streaming Protocol (RTSP)
- Resource Reservation Protocol (RSVP)
- Internet Protocol (IP) Multicast

Streamed video does not work extremely well over TCP since it requires enforced reliability and the application will keep waiting for retransmission of any dropped packets. Instead, UDP is frequently used since it handles these conditions better. UDP uses IP to transmit the data unit, or "datagram" but does not divide the data stream into packets for reassembly at the client end, although it does not necessarily put the datagrams in the correct order. The datagrams are reassembled in the correct order at the application end.

Real-Time Transport Protocol (RTP) is a UDP protocol that provides payload identification, sequence numbering and time stamping. It allows packets to be transported out of order and reassembled in the correct order at the receiving end. RTP is used with its companion Real-Time Control Protocol, which provides data packets to monitor data distribution quality.

RTSP is really an application level that uses many transport protocols including TCP, UDP, RTP and IP Multicast. It supports both unicast and multicast applications and provides more front end capabilities including playback and seeking. Real Networks video players are commonly known RTSP clients.

RVSP allows bandwidth reservation, memory and CPU resources to be dedicated to the video streaming application so Quality of Service (QoS) can be obtained. This protocol requires that all network components such as routers, switches and firewalls are configured to support it.
IP Multicast allows one-to-many services for video distribution, thus allowing better bandwidth and network efficiencies. Similar to RVSP, IP Multicast requires that all routers in the system are configured to support it, although some applications, such as Real Player, are able to bridge non-multicast enabled network segments. IP Multicast enabled routers query their groups to identify the processes currently belonging to each group. These processes, in turn, request to enter or leave a group.

Video Players and Plug-Ins

There are a number of different video players available for playing and controlling video playback on the desktop. Some of these are standard downloadable video players such as Real Networks RealOne video player, Apple's Quicktime and Microsoft Windows Media Player (which comes installed with PCs running the Microsoft operating system. Other players are specific to a certain vendor's codec or video server and can often be downloaded as a plug-in for viewing video over the internet within a browser. One example of such a player/plug-in is provided by Axis Communications. These commonly available video viewers can be used stand alone on the desktop to view video along the I-105 corridor by simply opening the player and entering a URL or "link" to the selected video signal. These players can, and often are, integrated as a plug-in into another more comprehensive video control or traffic management application. These applications will be discussed later in this section.

4.3 Video Servers

The method for capturing, converting, caching and distributing video over the network has evolved considerably over recent years. Not too long ago, the only real method for storing and reviewing video was with video cassette recorders (VCRs). In a traditional security application, multiple video cassette recorders or time-lapse video cassette recorders would be deployed and connected to analog NTSC video sources. Analog video would be recorded, stored and played back on analog video display devices (e.g. TV Monitors) when necessary. With the advent of digital video coding and compression, more advanced and efficient means of capturing, storing and serving video, in near real time, over the network are now available. These methodologies are listed and described below.

- ***Internet Protocol (IP) Cameras*** – IP cameras, also called network cameras or web cameras, were first available in the mid-1990s and are now widely available. Many of these cameras are simple moderate resolution units made for home or office use to allow viewing of events over the internet or LAN. These early inexpensive units were not ruggedized for outdoor environments or extended use and did not have the imaging and technical capabilities of the more traditional CCTV cameras used in traffic surveillance applications. Now, the IP camera technology has caught up with the analog cameras and multiple high-end units are available and in field use for ITS purposes. These units come with complete pan, tilt, zoom control and offer high-end digital signals right out of the camera housing so they can be connected directly into the Ethernet network. One such vendor producing these cameras for ITS applications is called Axis Communications.
- ***Video Codecs/Servers*** – Hardware and software video encoders/decoders (codecs) have been available for years using any of the video compression techniques or standards described above. Now, these same elements both convert the analog video signals to compressed digital format and serve them directly over the network so they can be viewed directly on user desktops. These video codecs come in two varieties – hardware or software versions. Hardware video codecs are appliances with custom chipsets. They can handle multiple channels of video and can either encode or decode on each channel. They can be more expensive for multiple viewers and lack flexibility for viewing from multiple encoder brands or types. Software codecs are basically computers (e.g. PC-based) running software video compression algorithms. These can be more flexible than hardware codecs by

handling video from different encoders, but are often more inefficient in terms of CPU usage and the time it takes to encode and/or decode the video.

Often, systems deploy a combination of hardware encoders with software decoders. For example, a hardware encoder can be used to compress the video in a certain format and a software decoder or viewer, such as RealOne or Quicktime, can be used to decode and view the video on the desktop.

- ***Digital Video Recorders (DVRs)*** – Digital video recorders are widely available for commercial and home use (e.g. TiVo) for recording analog video signals and storing them on hard drives for easy playback at a later time, even within seconds of just recording the original image. These units now come equipped with network interface cards so they can be plugged into the IP LAN and distributed across an enterprise network for viewing on any end-user device connected to the system. This is essentially one step up from a VCR. Disadvantages come with trying to capture and serve multiple videos across the network. Since DVRs are essentially single-channel units, many of them would be required to serve video on a multiple video network such as the I-105 Corridor video system. This configuration also lacks the efficiencies and intelligence of a single multi-channel video server implementation.
- ***Content Distribution Video Servers*** – Content Video Servers and Real-Time Video Servers are the two basic types of multi-channel network video distribution servers. Content Distribution Video Servers deliver pre-recorded video image files via the network or internet. One typical example is the way television and movie studios allow internet users to view TV or movie previews. Numerous canned video image clips in compressed format are stored on a centralized server, users access the studios' website, click on a clip and the video file is fed from the server to the end user via the web, buffered on the user's machine and played in a video player/decoder. In many cases, the file can actually be downloaded from the centralized server, stored on the user's machine and replayed directly from the PC hard drive.
- ***Real-Time Distribution Video Servers*** - When video is needed in real-time or near real-time, content distribution servers fall short due to the latency involved with the content distribution techniques. Real-Time Distribution Servers remove these latencies by receiving video directly, encoding the video in real time (when required), hosting the video and managing it for the network environment. In some solutions, the real-time video distribution serving capabilities are distributed across the network. Examples of two vendors that do this are Broadware and TLC Watch. With the Broadware solution, video is encoded at the source camera location (multiple protocols or profiles can be used) and interactive media servers manage, store and distribute the video using proxy processes. Broadware also offers application servers and client viewing tools to allow other systems to interface to their system or for end users to view and control video directly.

4.4 Video Management Software

For the I-105 Corridor project, video will be distributed via the network and be displayed and controlled on operator desktops which are assumed to be standard personal computers running the MS Windows operating system. Video from thirty (30) CCTV cameras located within nine (9) different cities and LA County will be viewable and controllable from workstations located at the each of the cities' Local Control Centers (LCC) and the Sub Regional TMC located at the LACDPW facility in Alhambra. At the local city level, city operators will be able to view and control video on their local desktop for the camera locations within their city limits as well as cameras from adjacent cities, within an established priority control scheme.

There are a number of choices available for common centralized control software:

1. A customized software application developed to interface with each of the cities systems and cameras, built per the agency's identified user and system requirements. This is the most expensive option and will be longest to implement and test.
2. Integrate the CCTV control into existing traffic signal control application to allow signal control and video control on a single user interface. This options also involves software customization and some degree of additional cost and time.
3. Utilize the CCTV interface and control capabilities of existing traffic signal control software that already has these integrated capabilities. If such features are already integrated into the traffic signal software system such as Icons and i2TMS, the cost to implement would be minimal, although some customization may be required to accommodate distribution video selection control from multiple different city and agency components (i.e. CCTV cameras and/or video servers).
4. Purchase a third party CCTV control application developed to interface with existing CCTV cameras and video serving components. These software applications are available from the video server vendors directly and have been generally designed to interface directly with their hardware products or a certain suite of hardware products. Examples include Broadware, TLC Watch and Cornet among many others. There is also other third party software designed to work and integrate with a wide range of video servers, codecs and CCTV control protocols. One such example is the Cameleon ITS product from 360 Surveillance.

A detailed presentation and analysis of centralized video software solutions will be provided later in this document. It will include information regarding the available off-the-shelf software solutions, their features, capabilities and suitability as a solution for the I-105 Corridor project.

5 VIDEO DISTRIBUTION SYSTEM ARCHITECTURE

5.1 Possible Architectures

There are basically three architectures that could be employed for video distribution. In general, they are fully distributed, partially distributed, and single point. For this exercise, we will consider three main factors when deciding upon architecture:

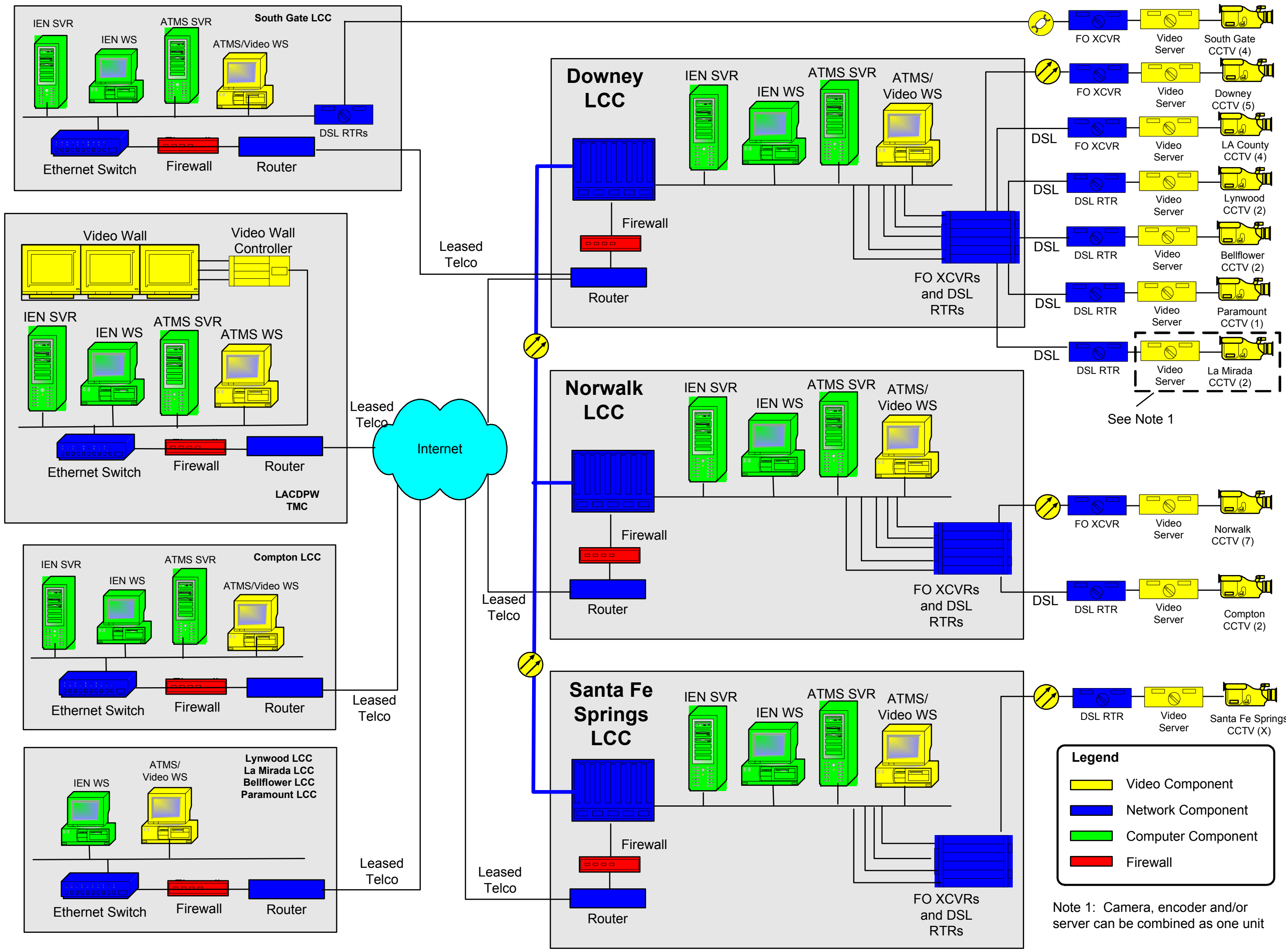
- Accessibility
- Scalability
- Maintainability

5.1.1 Each Camera Acting as a Video Server

Shown in figure 5-1, each camera acts as a video server and is directly accessible by any authorized entity via the communication infrastructure. This architecture relies on 'IP cameras' or an analog camera paired with a compact video server in the field. Hence, this architecture is considered fully distributed. Generally, this architecture affords maximum openness, but has negative maintenance and manageability implications. Following is a breakdown by factor:

- Accessibility – Cameras are readily accessible to any entity connected to the network. Access control must be managed on a camera by camera basis. Camera control is simplified as any operator basically accesses the camera directly.
- Scalability – This architecture readily allows for adding more cameras. As long as the video server can serve the consumer need with a single video stream, then there is no issue with this architecture. However, if the latter is not the case, then this architecture is not viable as many cameras are accessed via a DSL link which is limited to 384 Kbps. This architecture has a single point of failure for each camera and no means to provide for redundancy.
- Maintainability – Operating under the assumption that most of the maintenance lies with the video server (after initial camera installation) then this architecture has the biggest maintenance overhead. The latter is due simply to the sheer number of video servers involved, whereas even one video server per operation center would only amount to 10. The more cameras that are added, or the more consumers there are, maintenance will increase significantly. Any physical issues with the video server will require a visit to the field.

Figure 5-1: Field Video Server Architecture

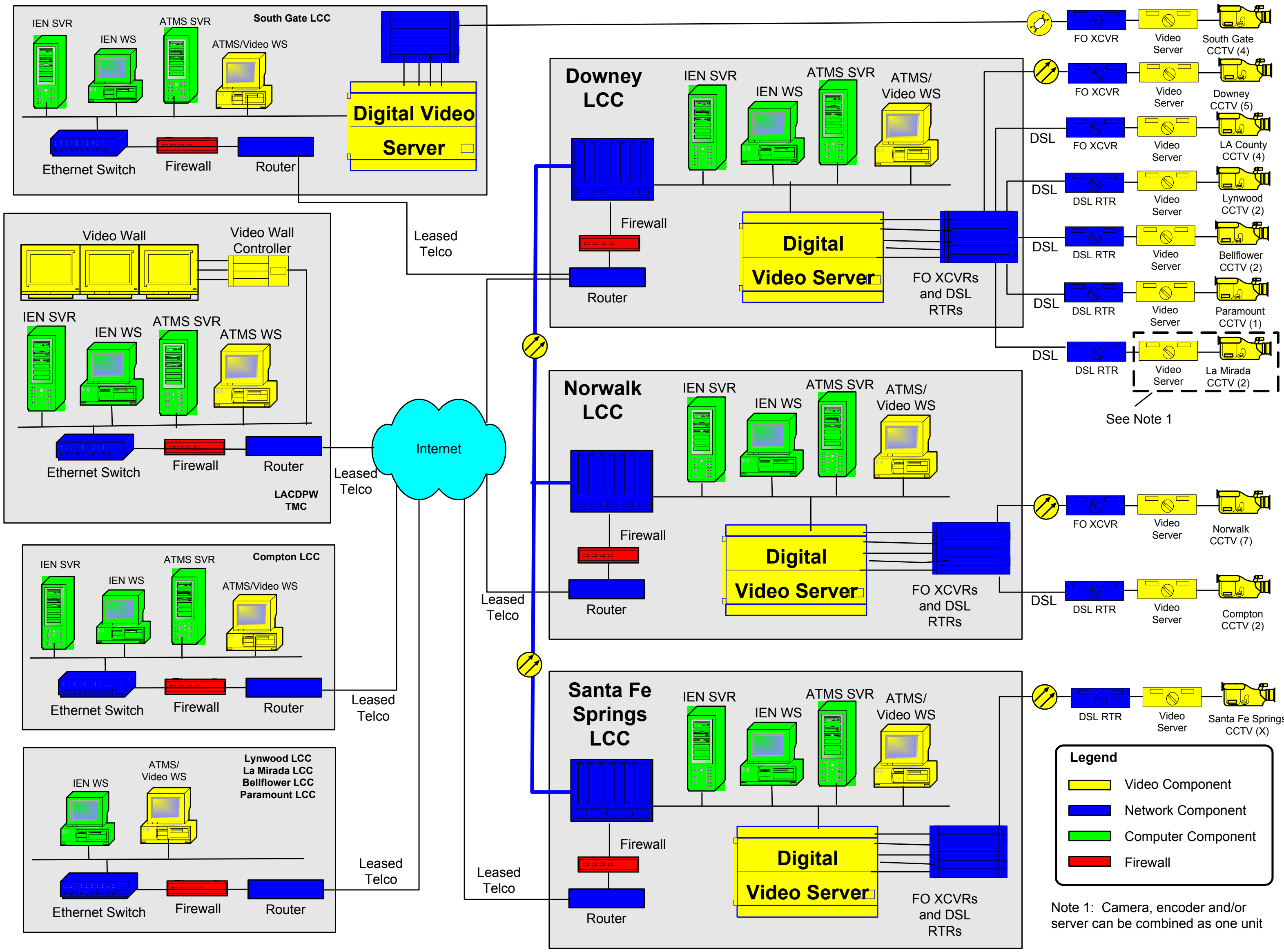


5.1.2 *Multiple Video Servers Strategically Located*

Figure 5-2 illustrates multiple video servers that are strategically placed at various operation centers collecting n-number of camera feeds and publishing them via the communication infrastructure to their intended destinations. These video servers can receive analog video directly and convert it to digital format or can receive already coded and compressed digital signals. For clarity, this architecture relies on simpler field encoders which are responsible for only sending a video stream back to a video server and providing control to the camera. This places the onus of system maintenance and manageability upon the operation centers hosting a video server. In general, this architecture affords the most flexibility to accommodate the three factors.

- Accessibility – Camera accessibility is governed by the operation center hosting the video server and the network link between the center(s) in question. A level of dependency is imposed on operation centers not hosting a video server. Access control is more centralized than in the previous architecture as there will be fewer video servers to administer. Camera control transpires via a video server rather than directly at the camera.
- Scalability – This architecture also allows for readily adding cameras, but a bit more simply. Adding cameras in this architecture is a matter of 'pointing' a stream to an existing video server as opposed to integrating a new video server every time a camera is added. Camera bandwidth is not an issue as each camera will always generate only one stream to a video server. Bandwidth between operation centers is usually greater than that of a connected camera, which better facilitates distributing video streams between centers. This architecture has the ability to provide for redundancy to eliminate the video server as a single point of failure.
- Maintainability – This architecture is simpler to maintain as maintenance and manageability are more centralized. Even if each operation center had its own video server, there would only be 10 video servers as opposed to 29 in the previous architecture. Also, it is likely that an operation center is manned so that any issue with the video server can be more readily addressed than when a video server resides in the field.

Figure 5-2: Distributed Video Server Architecture



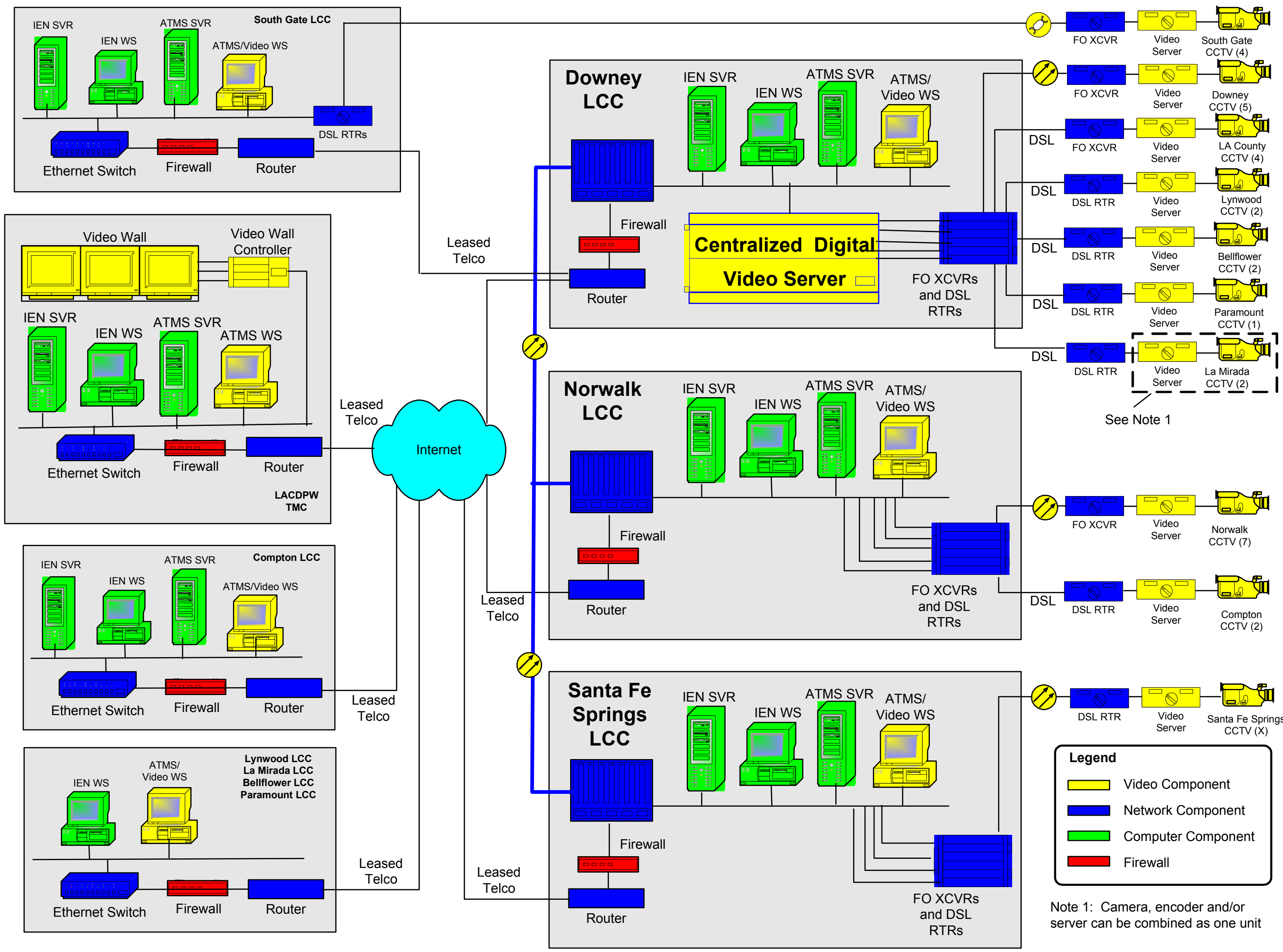
5.1.3 Single Master Video Server

Figure 5-3 illustrates a single master video server collecting all camera feeds and publishing them via the communication infrastructure. This architecture places the onus of system maintenance and manageability upon the single operation center hosting the video server. This may be the simplest architecture in logical terms, but is not necessarily the most efficient.

- Accessibility – Camera accessibility is governed by the single operation center hosting the video server and the network link to the center. A level of dependency is imposed on all operation centers except the one hosting the video server. Access control is completely centralized. Camera control transpires via a video server rather than directly at the camera.
- Scalability - This architecture also allows for readily adding cameras, but a bit more simply. Adding cameras in this architecture is a matter of 'pointing' a stream to an existing video server as opposed to integrating a new video server every time a camera is added. Camera bandwidth is not an issue as each camera will always generate only one stream to a video server. In this architecture, an outgoing stream from the video server may very well share the same network link as the originating incoming stream as a result of having only one video server. The latter could pose a scalability issue as more cameras are added. Unless multiple network links are established to the operation center hosting the master server, a downed link would be a single point of failure making all cameras unavailable.
- Maintainability – Having a single video server or servers in one location makes for the simplest maintenance scheme. However, the bulk of the maintenance burden falls on the hosting operation center, and if there are not adequate resources to meet the maintenance demands, then all dependent operation centers may not receive the quality of video service desired.

In this scenario the video server should be most central to all cameras involved as well as to the operation centers involved. This scenario allows for full centralized control of camera and video access. However, this scenario also does not utilize bandwidth efficiently as video streams coming into the video server will likely wind up sharing bandwidth with streams going out for remote destinations.

Figure 5-3: Centralized Video Server Architecture



6 VIDEO SYSTEM EVALUATIONS AND RECOMMENDATIONS

This section of the report will present evaluations for the four (4) critical I-105 video distribution system evaluation areas, which includes the required video system hardware and software components. The items that will be evaluated are:

1) Video Distribution Architecture
2) Video Codec and Video Compression Standards
3) Video Servers
4) Centralized Video Software

The four video evaluation areas will be completed in the order presented above since the recommendations provided in some of these areas are crucial to the assessment of some of the other items being evaluated. For example, recommendations related what is the most appropriate video compression standard relates directly to the video codec or server evaluation section since some vendors only support certain standards. At the conclusion of each section, recommendations will be provided on the most suitable alternatives and suggestions will be provided for the next steps for procurement and implementation.

6.1 Video Distribution Architecture

Three different video distribution architectures were presented in the previous section. Table 6-1 below summarize the advantages and disadvantages of each.

TABLE 6-1 Video Distribution Architectures

Architecture Alternative	Advantages	Disadvantages
Field Video Server Architecture	• Can reduce overall costs since serving can be combined with codec purchase • Reduces need for centralized server hardware and software • Many vendor choices are available for video encoder/server units • Reduces single points of failure compared to other two options	• Requires higher bandwidth to camera sites to meet multicast requirements • Can have issues with performance for larger video serving applications • Moves video serving function to field, thus increasing system configuration times • Limitations to vendor specific viewers • Limits scalability, especially with respect to bandwidth limitations to each camera site • Networks must be configured and "opened" all the way to the field
Distributed Video Server Architecture	• Allows for redundancy and backup serving capabilities • Many video servers support multiple compression algorithms, codecs and control protocols • Good scalability options with some	• More hardware components to maintain at multiple locations • Can complicate network configuration to allow access to multiple servers from multiple agency facilities

Architecture Alternative	Advantages	Disadvantages
	servers • Limits network security access points to LCCs • Multiple video server models available in both analog and digitial input varieties • Allows direct control for hosting agencies with more cameras • Simplifies field-to-center installation and configuration	
Centralized Video Server Architecture	• Single location for system installation and maintenance • Simplified installation and configuration • Limits network security access points to one LCC • Can reduce overall capital costs • Reduced maintenance • Many video servers support multiple compression algorithms, codecs and control protocols • Good scalability options with some servers	• Single point of failure • One agency responsible for video distribution for all agency jurisdictions • No system redundancies • Higher Internet bandwidth requirements for hosting agency • Makes local agency control more difficult since more remote connections are required to centralized site

Recommendation: It is recommended that the distributed video server architecture option be adopted for the I-105 corridor project since it offers redundancy and backup serving capabilities plus it allows more direct access and control for the hosting agencies of Downey, Norwalk, and Santa Fe Springs which have more cameras to control in comparison to the other cities. In addition, the configuration allows simplified field-to-center installation and configuration. The centralized video server architecture would require all field cameras, regardless of location and proximity to the centralized site, be configured and connected through the network to one site, making installation more difficult. The centralized option also introduces an architecture with a single point of failure. The field server architecture is not desired primarily due to the bandwidth limitations to support video multicasting.

6.2 Video Codec and Video Compression Standards

Selection of the appropriate video compression standard or algorithm is an important step toward selecting the correct video encoders, decoders, video servers and even the desktop video viewing and control application. As is typically the case within certain digital video networks, certain technical limitations present themselves that warrant the use of certain video compression techniques. For example, there may be a pre-existing application capable of viewing streaming video on the desktop, and this application may be integrated with only one type of video player (e.g. Quicktime, RealOne, etc.). Based on this, the video server and/or codecs may need to be selected so that they are supported by the end user application. Similarly, as is the case with the I-105 Corridor Project, the field communications network provides limitations on the available communication bandwidth for transmission of the video from the field to the LCCs. For I-105, 384 kbps video is a limitation for the cameras that will be connected to the center using SDSL communications. This section of the report will evaluate the various standard video compression algorithms and provide a recommendation on which one or ones are most appropriate for this project.

Table 6-2 – Video Compression Standards

Standard	Application	Method	Bit Rates	Resolution	Frame Rate	Latency	Quality
MJPEG	IP Networks	DCT	10 kbps- 20 Mbps	Any	1-30 fps	Low	Excellent Broadcast
JPEG2000	IP Networks/Web	Wavelets	10 kbps- 7.5 Mbps	160x120 320x240	1-30 fps	High	Very Good
MPEG1	VCD	DCT	1.5 Mbps	352x240 320x240	1-30 fps	Medium	Moderate VCD
MPEG2	DVD/HDTV IP Networks	DCT	2 Mbps- 8 Mbps	720 x240 640x480	24-20 fps	Medium	Excellent HDTV/DVD
MPEG4	Internet	DCT Wavelet	10 kbps- 10 Mbps	640x480 to 4096x4096	1-30 fps	Medium	Very Good DTV
H.261	Video Conferencing	DCT	16 kbps- 1.5 Mbps	176x144 to 1408x1152	10-15 fps	Low	Moderate Videoconf.
H.262 (MPEG2)	DVD/HDTV IP Networks	DCT	2 Mbps- 8 Mbps	720 x240 640x480	24-20 fps	Medium	Excellent HDTV/DVD
H.263	Video Conferencing	DCT	30 kbps- 2 Mbps	176x144 to 1408x1152	10-15 fps	Low	Moderate Videoconf.
H.263+	Video Conferencing	DCT	30 kbps- 2 Mbps	176x144 to 1408x1152	10-15 fps	Low	Moderate Videoconf.
H.264/26L	Videoconf/ Internet	DCT	10 kbps- 10 Mbps	640x480 to 4096x4096	1-30 fps	Medium	Very Good DTV
Wavelet	LAN/Web/ Videoconf.	Wavelets	10 kbps- 7.5 Mbps	160x120 320x240	8-30 fps	High	Very Good

Based on the information in Table 6.2 above as well as the discussion in Section 4, there are a number of standard video compression techniques as well as some other non-standard methodologies accepted and in use in the industry. By simple process of elimination, several of the standards are not applicable or recommended for the I-105 project since the bit rates are not useable based on the bandwidth limitations of the I-105 communications network. While it is true, that some I-105 cameras will be connected via fiber and there is no real bandwidth issues in these cases, it is highly recommended that the system-wide design is consistent and incorporates the same video compression methodologies throughout and in turn, uses the same video codecs.

MPEG4, H.261, H.263, H.263+ and H.264 (part of MPEG4) are the video compression standards that meet the bandwidth requirements for this project. MPEG4 is the standard capable of providing the best quality at lower bandwidths in comparison with the H.261 and H.263 standards and inexpensive codecs are widely available from a number of vendors. Table 6-3 is a partial listing of multichannel video server and video codec vendors and models. These devices are listed together in one table since most single channel video encoders also act as video servers capable of video multicasting or unicasting across an IP network.

Recommendation: The recommendations for the I-105 project is to use MPEG4 video encoders in the field since they most suitably meet the I-105 project requirements for video quality at low bandwidths and are widely available on the market. In addition, there are a number of relatively high-end multi-channel video servers capable of integrating with the MPEG4 video encoders directly, offering a more homogeneous end-to-end compatible solution. Of the video encoders, it is recommended to use a unit that works within the environmental conditions required for this project from an established vendor experienced with the ITS applications. The Cornet VDO Streamer, TLC Watch TLC1100 and the Cohu Mavix MXR022 all meet these conditions and are recommended for use on this project. Other video encoders such as the Verint Smartsight, AXIS 241 and Axis SED-2100 can also be considered if the field environment can be maintained to support these units. It should also be noted that some vendors offer IP cameras (e.g. Axis and others) that can provide IP digital directly from the housing, another option for the I-105 project.

Table 6-3: MPEG4 Video Codecs and Servers (Partial List)

Manufacturer	Model	Input	Output	Storage Capacity	Camera Control	3rd Party Integration	Environmental Operating Temp
4XEM	IPVS1A	1 Analog	MPEG-4	None	Yes	No, Browser & Proprietary only	+32°F to +149°F
ACTi	SED-2100	1 Analog	MPEG-4	None	No	Yes + Browser	+40°F to +122°F
AXIS	241Q	4 Analog	JPEG, MPEG-4	None	Yes	Yes + Browser	+41°F to +113°F
AXIS	241S	1 Analog	MPEG-4	None	Yes	Yes + Browser	+41°F to +113°F
Broadware	Media Server	Up to 500 Digital Video Streams	MJPEG, MPEG-2, MPEG-4	Directly no, w\ BSS yes	Directly no, w\ BAS yes	Yes + Browser + BAS	Indoor Use Only
Cornet Technology	VDO Streamer 2/4	1 Analog	MPEG-2, MPEG-4	None	Yes	Yes + Browser + VDP Scope	-40°F to +167°F
Dedicated Micros	DV-IP series	4, 6, 10, 16 Analog	MPEG-4	80 - 600 GB	Yes	No, extensible via DM Java Development Kit	+41°F-113°F
Inscape Data	AirGoggle NVS410	1 Analog	MPEG-4	None	Yes	No, Browser & Proprietary only	Indoor Use Only
Inscape Data	NVS440	4 Analog	4 MPEG-4	None	Yes	No, Browser & Proprietary only	Indoor Use Only
Inscape Data	NVS440R	4 Analog	4 MPEG-4	120 GB	Yes	No, Browser & Proprietary only	Indoor Use Only
TLC Watch	TLC1100	1 Analog	MPEG-4	None	Yes	Yes + Browser	-4°F to +158°F
TLC Watch	TLC5200 Comm Server	Digital Streams	MPEG-4	None	Yes	N/A	+32°F to +131°F
VCS	VIP 10	1 Analog	MPEG-4	None	Yes	Yes + Browser	+32°F to +122°F
VCS	Videojet 10	1 Analog	MPEG-4 and JPEG	None	Yes	Yes + Browser	+32°F to +122°F
Verint	Smart Sight S1500e-T	1 Analog	MPEG-4	None	Yes	Yes + Browser	+32°F to +122°F
Verint	S1700 Series	4, 8, 12, 24 Analog	MPEG-4, up to 4 Mbps/stream	None	No	Yes, Cameleon. Also nDVR™, Loronix Video Manager® (proprietary)	+32°F to +122°F
Cohu	WeCE311	1 Analog	MPEG-4	None	Yes	Yes	+32°F to +140°F
Cohu	WeCE611	1 Analog	MPEG-4	None	Yes	Yes	+32°F to +122°F
Codu	Mavix MXR022	1 Analog	MPEG-4, WM9	None	Yes	Yes	+14°F to +149°F

6.3 Video Servers

Video servers come is a variety of shapes and sizes supporting a number of video compression techniques, some standardized and some not. A good majority of the MPEG4 video encoders available today, also act as video servers and can be connected directly onto the network. They can send video multicasts or multiple unicasts. They are equipped to digitize from one analog video channel to up to 16, 24 or more channels simultaneously.

Another major category of video server is the larger content video distributions servers or real-time video distribution servers. Of the models listed in Table 6-3, Broadware, TLC Watch, Inscape and Dedicated Micros fall into this category of real-time video distribution servers or systems. Other solutions also exist from companies like Honeywell and Siemens among others. The Broadware and TLC watch solutions receive direct digital video signals from the encoders (locally or in the field) and proxy these digital videos for distribution video via the LAN or Internet. They also can store and index the video for future playback. Broadware has been designed to integrate with a number of MPEG4 video encoders including VCS, Verint and Axis and comes with it's own centralized video control software. The TLC watch solution does the same, except it is design to work specifically with the TLC Watch encoders, but can be modified to work with others.

Recommendation: The recommendation presented earlier in this section is for a distributed video distribution architecture in which each of the major LCCs such as Downey, Norwalk and Santa Fe Springs each have their own video server. With this configuration, it is recommend that a real-time video distribution solution such as one offered by Broadware or TLC watch be implemented and the field video encoder selection be compatible with this centralized video server.

6.4 Centralized Video Software

A Centralized Video Software Solution is one that ties all of the distributed hardware and software components into a single, coherent and effective system. These solutions can be integrated into an existing traffic signal control application, as is depicted in Section 6.4.6, or can existing stand alone applications made integrate with existing off-the-self video components (e.g. servers, codecs and cameras). One solution is a purely software solution that relies on 3rd party hardware (Cameleon), while the others offer various levels of software & hardware combinations as well as various levels of 3rd party hardware support. These systems typically have two primary aspects to them, administration and use. Administrators must be able to configure components, users, and access levels, while users must be able to perform video related tasks, primarily viewing and camera control. Although at this level things appear relatively simple, to accomplish the described functionality, the proposed solution must communicate with, and be able to coordinate all the components involved. This evaluation is within the context of a distributed multi-site, multi-user environment, which brings some inherent minimum requirements to the top of the list for the system to be effective. Hence, the system should allow for

- Multiple user access per video stream across sites
- Various access levels across sites
- PTZ control for authorized users across sites

To improve usability which in turn could help acceptance of the solution and improve productivity, a set of functionality referred to as 'the nice to haves' could also be considered. Consequently, it would be nice if the proposed solution also has

- CCTV contention mitigation
- Camera Presets
- Video Stream Viewport Customization (e.g. window size, window position, etc)
- Bandwidth control

Lastly, when considering a solution, the flexibility and longevity of the proposed solution may play a role in the evaluation process. Flexibility, and indirectly longevity, is governed by

- Variety in hardware vendor support
- Extensibility of the solution (e.g. easy to use Application Interfaces)

6.4.1 360 Surveillance – Cameleon 4

Figure 6-1: Map Integration

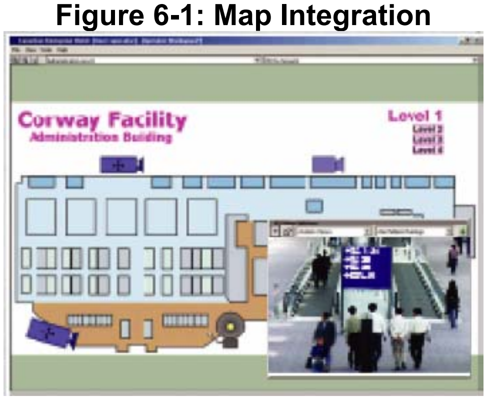
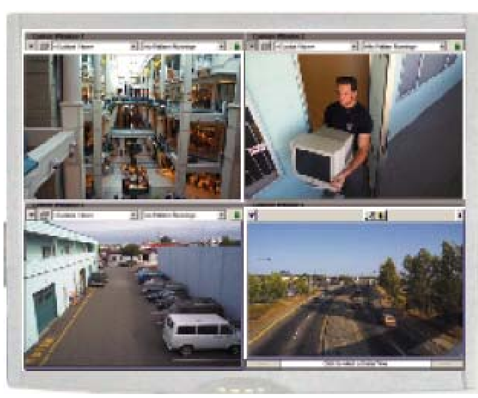


Figure 6-2: Multiple Cameras in Single View



Highlights

- Scales by adding servers and clients as needed. Cameleon supports client-server, client-multiple server and server-to-server architectures.
- User role management
- PTZ control
- Priority control prevents CCTV resource conflicts
- Customizable maps
- Configurable desktops on individual and multiple workstations
- Video Wall control
- Supports hybrid IP/Analog video systems
- Multi-Vendor support
- Video Compression formats determined by vendor devices used

Cameleon 4 is an application specifically written to provide advanced video control and management capabilities. Figure 6-1 illustrates Cameleon's map integration while figure 6-2 illustrates multiple cameras viewing on a single screen. Cameleon is already used in the ITS industry as well as the Security industry and has proven its value. This application provides the user front end for many other vendors' hardware, including encoders, decoders, video servers, and archiving components (e.g. DVR). Cameleon provides for the configuration of vendor hardware directly from the application providing ease of configuration. In addition to being able to manipulate hardware, the application allows for creating a user base and specifying access levels for a particular hardware infrastructure. The system is intended for multi-user use and also provides for resource contention and a high level customization from viewing configurations to specialized windows. Multi-vendor support at all levels is one of Cameleon's greatest strengths as it precludes being locked into any one specific vendor for hardware needs. More technical aspects such as video compression support and network protocols are governed by the devices used rather than the application itself. Figure 6-3 illustrates Cameleon's infrastructure capabilities.

Figure 6-3: Cameleon 4 Components in an Infrastructure

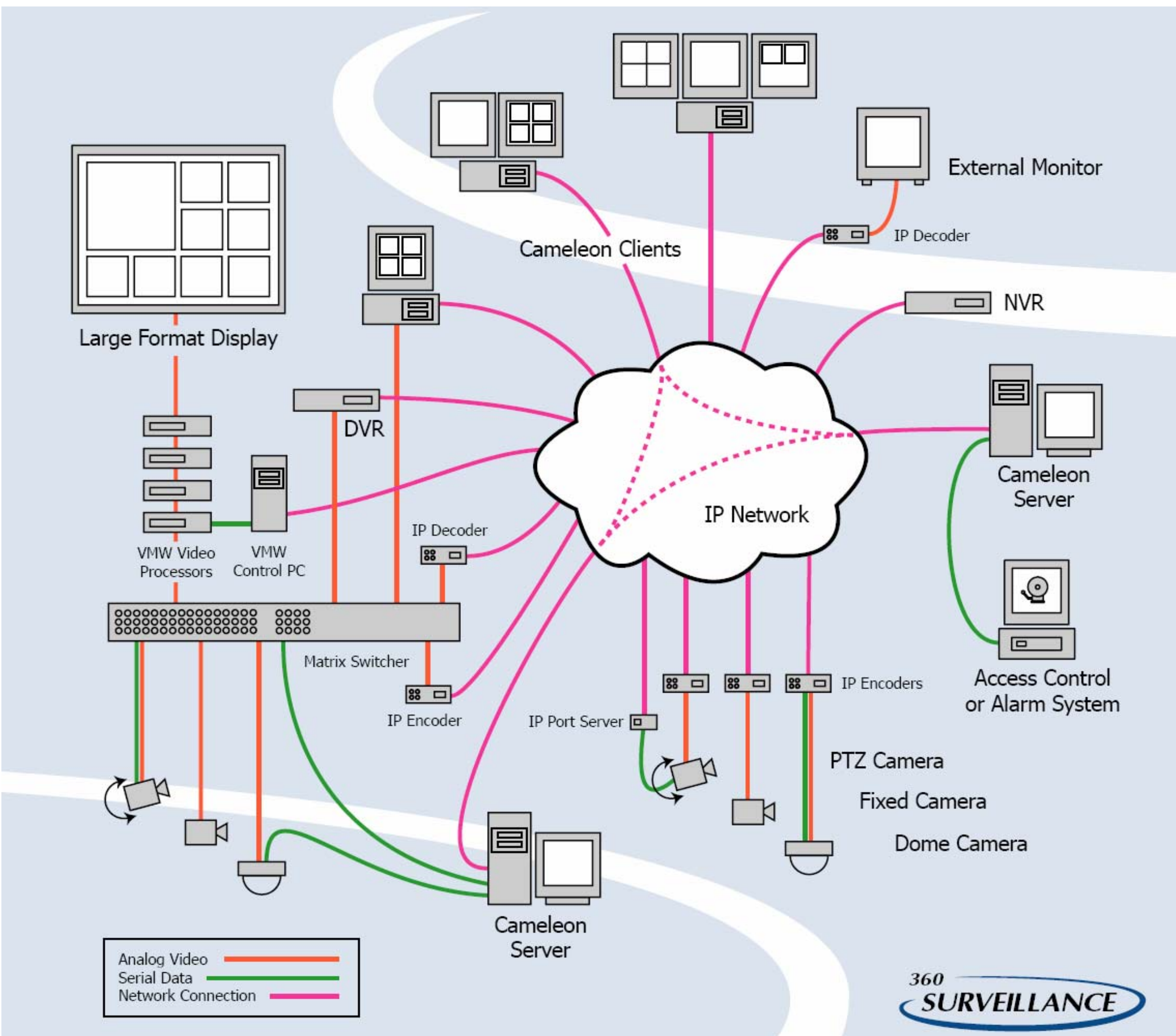


Table 6-2 provides a list of devices that Cameleon supports, but the Cameleon application also provides custom driver support.

Table 6-4: Devices Cameleon Supports 'Out of the Box'

Access Control Systems	**Access Control**
	Hirsch Velocity, Elpas Infant Protection System, MAS, Lenel, Ccure, ISS Summit NT, All systems that support serial switching of video matrix switchers based on alarms
ADEMCO	**Switchers**
	VideoBloX
	VCRs
	AVR960SV
	CCTV Keyboards / Joysticks
	Ultrak KEGS5000
American Dynamics	**Cameras**
	SpeedDome
	Switchers
	All ASCII Protocol switchers
	Multiplexers
	ROBOT Quad
	CCTV Keyboards / Joysticks
	AD2078
	DVRs
	Intellex
Avitech	**Display Systems**
	Virtual Monitor Wall
	Video Control Systems
	Video Control Center
Axis	**Network Cameras**

	AXIS 205, AXIS 230, AXIS 2110, AXIS 2120, AXIS 2130, AXIS 2400, AXIS 2401, AXIS 240S, AXIS 240Q, Panorama
	PTZ Cameras
	Server PTZ
	Video Servers
	AXIS 250S
Barco	**Video Wall Controllers**
	Argus
Cohu	**Cameras**
	iDome, 3830 Series, 3850 Series, ER2221A
Cornet	**Switchers**
	VTX Series, MTX Series
	Video CODECs
	CDX encoders, CDX receivers
Cybermation	**Switchers**
	System6, System 5
Dedicated Micros	**Recorders**
	Digital Sprite 2
Enerdyne Technologies	**Video Encoders**
	1000 Series, 2000 Series
	Video Decoders
	1000 Series, 2000 Series
Extron	**Switchers**
	Extron Protocol switchers
	VGA Switchers
	SW2/4/6 VGArs, SW2/4/6 VGA Ars
GE	**Programmable Logic Controllers**
	Fanuc 90-30, Fanuc 90-70

	Human Machine Interfaces
	Fanuc Cimplicity HMI V5.0
GYYR	**DVRs**
	DVMS 100
iMPath	**IP Codecs**
	1000 Series encoders, 1000 Series decoders, 4000 Series encoders, 1400 Series encoders, VSG Series encoders, VSG Series decoders
Integral Technologies	**Recorders**
	DVR
Javelin	**Cameras**
	J0308, J0408, J0508, VCL Dome
	Switchers
	All Javelin switchers
Jupiter Systems	**Display Systems**
	Fusion 960 Display Wall Processors
Kalatel	**Cameras**
	CyberDome
	Switchers
	All ASCII Protocol switchers
Knox	**Switchers**
	8x8, 16x16, 32x32, 64x64, 256x256, Chameleon HB
Loronix	**DVRs**
	Including Wavelet recorders, Vision recorders, Enterprise MP recorders, VR4000/6000 recorders, and VR1000 recorders, with SmartSight S1500e series, S1700e series, S1100w , and S3100 series encoders

Mavix	**Encoder/Decoders**
	MR100 encoder/decoder, MR150 encoder/decoder, MR152 encoder
NICE	**DVRs**
	NiceVision Harmony
NTI	**VGA Control**
	8x8 VGA matrix, VGA source (PC), VGA destination
ObjectVideo	**Recorders**
	VEW
Panasonic	**Cameras**
	PanasonicPTZ
	Switchers
	350 Keyboard, SX150, SX550, SX850, WV-CS854
Pelco	**Cameras**
	All Spectra Series Dome Systems, Esprit
	Switchers
	6700, 6800, 9740 (versions 7 & 8), 9760 (versions 7 & 8), 9760-DT4, 9760-DT, 9770
	DVRs
	DX9000, DX9100, DX9200, DX8000
	Multiplexers
	Genex
	IP Codecs
	PelcoNet 300, PelcoNet 350, PelcoNet 4000
	CCTV Keyboards / Joysticks
	KBD-300
	VCRs
	TLR-3168, TLR-3096

	Contact Modules
	9760-ALM, 9760-REL
	Display Systems
	MultiViewer virtual monitor wall
Philips - Bosch - Burle	**Cameras**
	Fixed speed, Variable speed
	Switchers
	Allegiant LTC 8100, LTC 8200, LTC 8300, LTC 8500, LTC 8600, LTC 8800, LTC 8900, System4
QuickSet	**Mobile Pedestals**
	QuickEye, QPT20
RiteStar	**Indoor LED Signs**
	RiteStar Electronic Text Displays
SmartSight	**Digital Video Encoders**
	All models
Sony	**Cameras**
	EVI-D30, NetCam SNC-RZ30
Teleste	**Encoder/Decoders**
	EASI MPEG-2 encoders, EASI MPEG-2 decoders
Ultrak	**CCTV Keyboards / Joysticks**
	KEGS5000
	Cameras
	Ultrak PTZ
VBrick	**IP Codecs**
	4200 Series encoders, 4300 Series encoders, 5200 Series decoders, 5300 Series decoders, 6200 Series codecs, Decoder monitors
Vicon	**Cameras**

	Surveyor Dome
	Switchers
	Nova, Nova 1422, 1500 CDU/CPU
	Multiplexers
	AurorA2000
	DVRs
	Kollector
Vivotek	**Cameras**
	IP2111, IP2112, IP2121, IP2122, IP3111, IP3112, IP3121, IP3122, IP3132, IP3133, IP3135, IP3136, PT3112, PT3113, PT3114, PT3122, PT3123, PT3124
	Video Servers
	VS2101, VS2402, VS3100, VS3102

6.4.2 *Broadware - Application Server (BAS)*

Figure 6-4: Camera Selection with Control Pad

Figure 6-5: Camera Selection via Map

Highlights

- Manages an unlimited number of Media Servers, cameras, and viewers
- Supports multiple video formats (MPEG-1, MPEG-2, MPEG-4, MJPEG, H.264)
- Customizable views of cameras across multiple sites
- PTZ and presets
- User role management
- Secure login, unlimited number of users
- Detailed reporting on user and event activities
- Maps

The Broadware Application Server (BAS) is an enterprise solution for managing Broadware Media Servers (BMS), cameras, users, and video displays. It meets the diverse needs of system administrators operators by providing multiple web-based display consoles to configure, manage, display, and control video throughout a customer's IP network. A single BAS can manage a large number of BMS, cameras, and users. Figure 6-4 illustrates viewing multiple cameras on a single screen with a camera control pad, while figure 6-5 illustrates a camera selection from a map which was done via 3rd party integration

(Ortega Systems). Figure 6-6 provides an overall view of the Broadware Media Platform. Note that the illustration contains all of Broadware's components, but this analysis document only concerns itself with the BAS and BMS.

Figure 6-6: BAS & BMS in the Broadware Media Platform

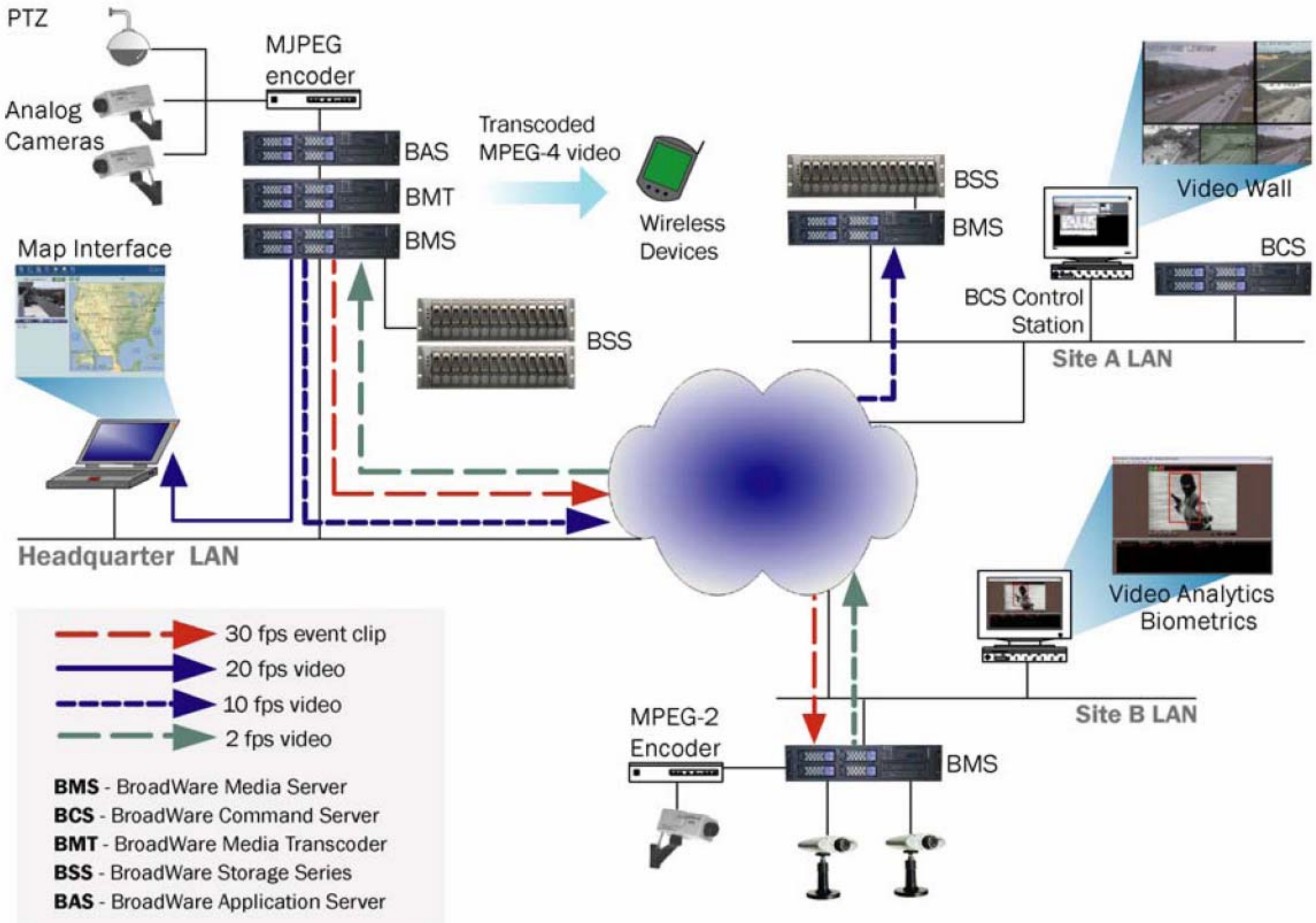


Table 6-3 lists a number of video appliances that the BMS and BAS can interoperate with.

Table 6-5: Devices Broadware Supports

Video Appliances	
AXIS	2100 Network Camera
	2120 Network Camera
	2130 Pan-Tilt-Zoom Network Camera
	2400 Video Server
	2400L Video Server
	2400+ Video Server
	2401 Video Server
	2401L Video Server
	2401+ Video Server
	2411 Video Server
	2420 Network Camera
	205 Network Camera
	250S MPEG-2 Video Server
	230 MPEG-2 Network Camera
	241Q Video Server
	241S Video Server
	210 Network Camera
VCS	VideoJet 10
	VideoJet 1000
PelcoNet	NET4001A
Sony	SNC-RZ30N Network Camera
Camera Support	
	Any fixed analog camera.
	Pan-Tilt-Zoom Support o AXIS 2130 o Bosch Autodome o Canon VC-C3 o Cohu, Cohu legacy o Pelco

6.4.3 TLC Watch - TLC5500

Figure 6-7: Overview Map, Selected Camera, Video Wall, and Event List

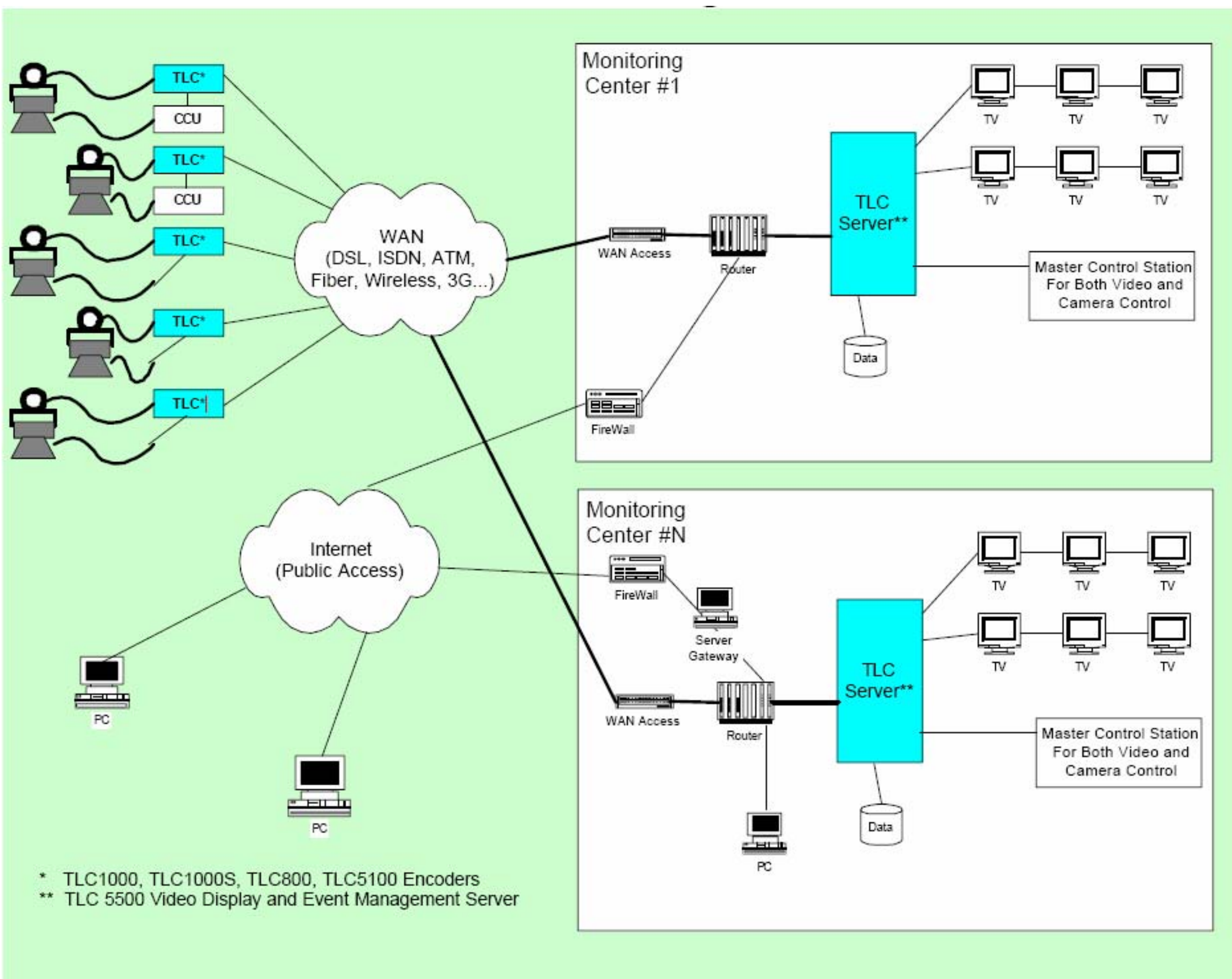
Figure 6-8: Zoomed Map, Selected Camera, Video Wall, Camera Control Pad, and Event List

Highlights

- Manages a video display wall supporting up to 8 video outputs
- Supports GIS maps
- Manages events
- PTZ and up to 10 presets
- Multiple site support in a Master/Slave configuration
- Supports MPEG-1, MPEG-4, and H.323 video compression
- Provides for public web access

The TLC 5500 is a "Video Surveillance Center" in-a-box. It provides a complete solution for building a remote security video surveillance center or a traffic video management center. The TLC Model 5500 system is an all IP based video surveillance solution. It is built to bring today's surveillance management system to the next generations. Instead of a hardware video matrix switch, the TLC 5500 uses a software based video switching system. The TLC 5500 includes a powerful database system that enables easy operations take over by remote centers. The database system contains the local streets and interstates maps, camera locations and traffic events locations. The TLC 5500 system also includes a web-based public interface. The TLC Server is composed of the TLC 5500s and TLC 5500 management stations, and includes a number of key functions for managing video display wall, managing GIS maps, managing events, and providing web access. Figure 6-7 illustrates the map in overview mode in the upper left, the video wall control pad in the lower left, a selected camera in the upper right, and an event panel in the lower right. Figure 6-8 illustrates a zoomed in map in the upper left, and a camera control pad mid right, while retaining the other elements in figure 6-7. Figure 6-9 illustrates the TLC5500 in a multi-center implementation.

Figure 6-9: TLC5500 Multi-Center Implementation



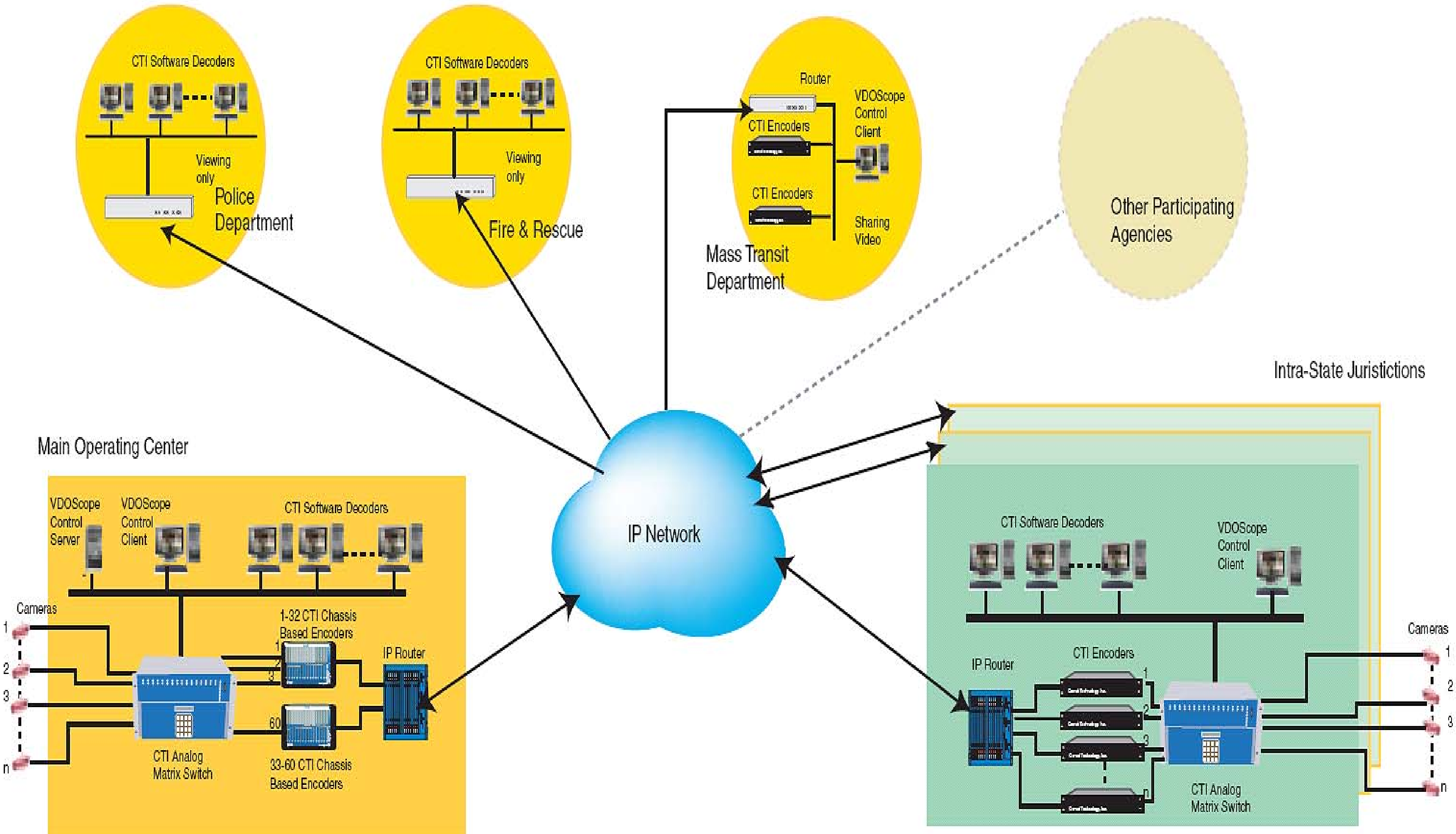
6.4.4 Cornet – VDOScope 2.0

Highlights

- Supports up to 24 operation centers, 1000 devices, and 400 users
- Geared towards multi-jurisdictional use model for sharing data
- Supports multiple video formats (MPEG-1, MPEG-2, MPEG-4, snapshot)
- Customizable views of cameras across multiple sites
- PTZ and presets
- Tiered access using multiple authority levels
- Detailed reporting on user and event activities
- GIS based map support
- Supports alternate vendor hardware as well as Cornet hardware

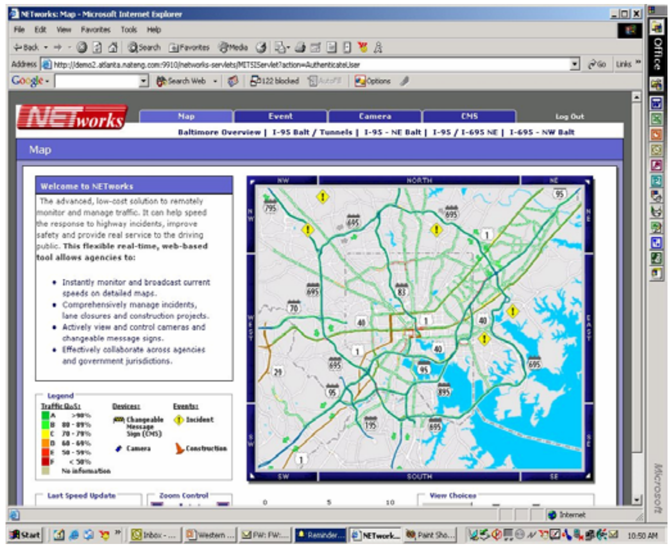
VDOScope 2.0 is a customizable, java-based software platform designed to manage closed-circuit video and communications systems. The system is designed for use within the intelligent transportation and security surveillance industries to collect, transmit, route, share, and display video among single or multi-jurisdictional closed circuit television (CCTV) surveillance systems. To support multi-jurisdictional users, Administrators designate access and override capabilities to users based on authority level. The system creates an audit log, user activity reports and status reports to track and monitor all activities on the system. VDOScope's GUI allows users to monitor feeds from multiple systems and specific devices. Each user can create a custom view of multiple locations simultaneously, while multiple users can view a single video stream simultaneously. Figure 6-10 illustrates VDOScope in a multi-jurisdictional implementation.

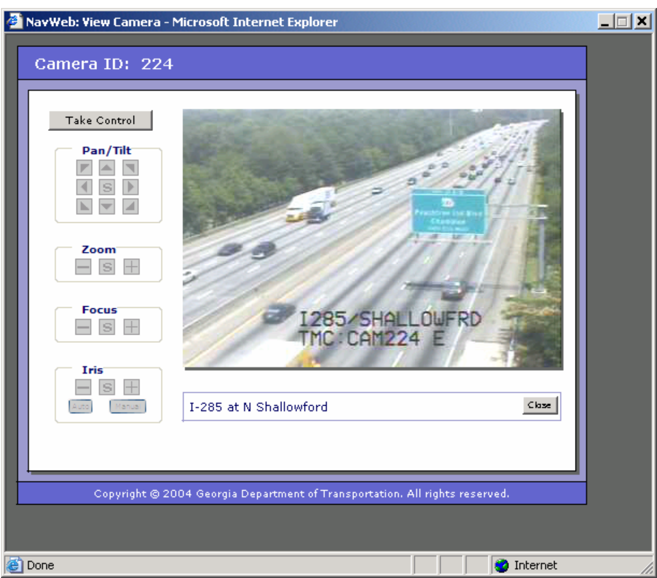
Figure 6-10: VDOScope in a Multi-Jurisdictional Configuration



6.4.5 NETworks

NETworks is an NET Corporation developed product. It is an integrated transportation management system with the capabilities of interfacing with and integrating multiple systems including: freeway management systems, arterial management systems, transit systems and traveler information systems. *NETworks*' functional capabilities include: monitoring and control of field devices; management of events (such as construction, lane closures, incidents/accidents, special events, etc), including coordinated response between agencies; management of recurring congestion; dissemination of traveler information; generation of real-time and historical reports; system configuration and administration.



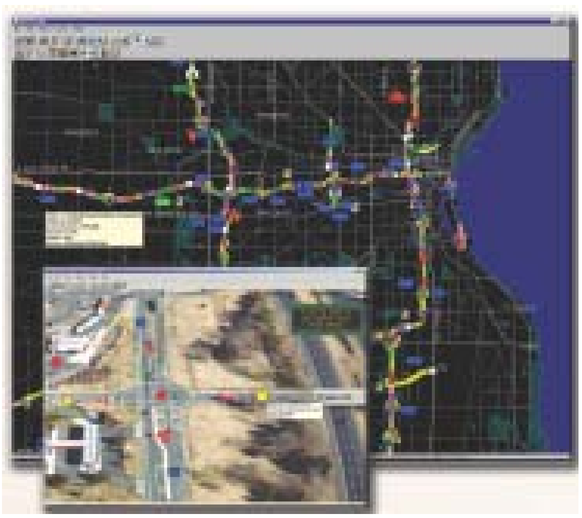


NETworks includes a map-based geographical user interface that allows for the monitoring and/or control of field subsystems such as: vehicle detection systems, dynamic message signs, closed-circuit television cameras, highway advisory radio, ramp metering systems, road and weather information systems, traffic signals and lane control signs. Event management functions include: event detection, verification, definition, monitoring, response and termination. *NETworks* can disseminate traveler information through various mediums, including web pages, kiosks, highway advisory telephone, highway advisory radio and information service providers.

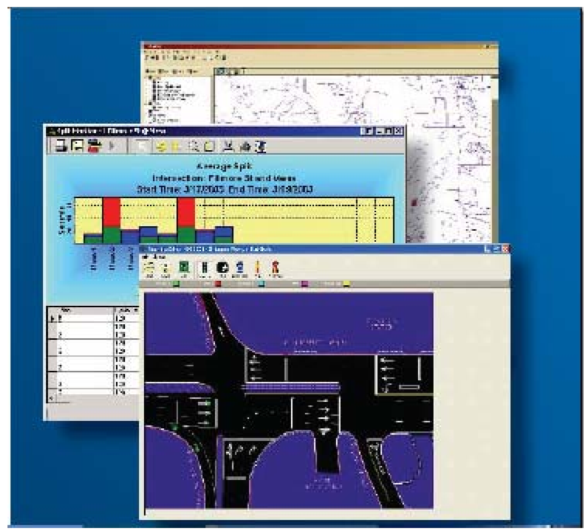
6.4.6 ATMS Systems with CCTV Support

The applications mentioned in section 6.1 provide for the management, distribution, and viewing of CCTV video streams. There are also a number of complete ATMS systems that support CCTV control and viewing. However, in these systems, CCTV manipulation is merely a capability of the overall system, and not intended to be a full scale video distribution management system. In light of the fact that this evaluation is within the context of ITS, ATMS applications are mentioned as viable options for camera control and viewing only. The ATMS systems provide certain features such as user management, security access, resource contention prevention via the core application, which in turn would be applied to the CCTV viewing functionality as well. These applications usually require additional hardware at the workstation to allow for the viewing of video stream data. Finally, the ATMS applications are most viable when they are already in place and the CCTV infrastructure is being added or upgraded, or when there is a need for an ATMS system in addition to CCTV management, control, and video distribution. Following is a short list of CCTV capable ATMS systems:

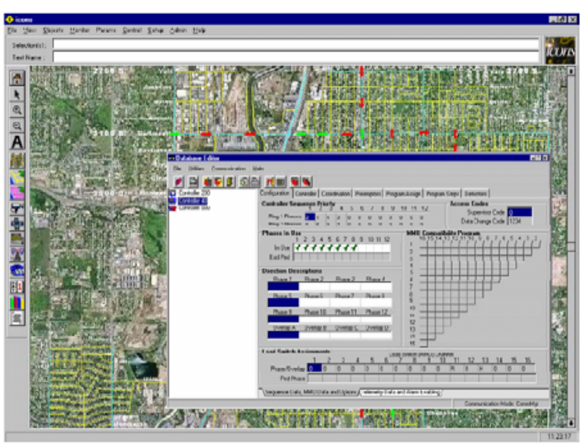
- Transcore Transuite



- Econolite Pyramids



- Econolite ICONS



- Siemens i2TMS

Table 6-6: Video Management Solutions

Manufacturer	Product	System Type	Map Support	Multiple Camera Access Control	Multiple Vendor Support
360 Surveillance	Cameleon	CCTV Management	Yes	Yes	Yes
360 Surveillance	Cameleon ITS	ATMS / CCTV Management	Yes	Yes	Yes
AMAG	Digital Video & CCTV Management	CCTV Management	Yes	Yes	Yes
Broadware	Broadware Application Server	CCTV Management	Yes	Yes	Yes
Cornet Technology	VDO Scope	CCTV Management	Yes	Yes	Yes
Econolite	ICONS	ATMS / CCTV Management	Yes	Yes	Yes
Econolite	Pyramids	ATMS / CCTV Management	Yes	Yes	Yes
Siemens	I2TMS & Nextview	ATMS / CCTV Management	Yes	Yes	Yes
TLC Watch	TLC5500	CCTV Management	Yes	Yes	No
Transcore	Video Control System	CCTV Management	Yes	Yes	Yes
Transcore	Transuite	ATMS / CCTV Management	Yes	Yes	Yes
NET	NETworks	Web-baseed ATMS/CCTV Control	Yes	Yes	Yes

Recommendation: The recommendation for centralized video control software solution is one that has the flexibility to operate with multiple vendors video cameras, video servers, video codecs, supports multiple control protocols and allows access to cameras via mapping tools. It is not recommended to use a solution that is limited to only certain field video hardware components or traffic signal software applications. The recommendation is to investigate Broadware, 360 Surveillance Cameleon and the NETworks product lines. These solutions offer a high level of vendor flexibility integrating with multiple video camera and video encoder vendors as well as video server systems.

APPENDIX A – GLOSSARY

Glossary

Algorithm:	Mathematical process used to compress and (in the inverse) decompress video and audio data.
BPS:	Bits per second.
CCIR:	French abbreviation for the International Radio Consultative Committee now referred to as ITU-R.
CCIR 601:	ITU recommendation for resolutions of video encoding the basis for MPEG-1 and MPEG-2.
CCTV:	Closed-Circuit television
CIF:	Common Intermediate Format; 352X288 pixels at 7.5, 10, 15, or 30 fps.
Codec:	Coder/Decoder; used to compress video and audio signals for digital transmission.
Component Video:	Video with individual signals for red, green, and blue, e.g. RGB.
Composite Video:	Video that incorporates all parts of the picture in a singe signal.
DCT:	Discrete Cosine Transform; two-dimensional compression technique that converts blocks of pixels to frequencies and coefficients.
DSL:	Digital Subscriber Line
DVD:	Digital Video Disk or Digital Versatile Disk
DVR:	Digital Video Recoder
FPS:	Frames per second
HDTV:	High Definition Television; very high quality digital television incorporating a number of technologies.
IEC	International Electrotechincal Commission (IEC) - International standards and assessment body for the fields of electrotechnology
IP:	Internet Protocol
ISDN:	Integrated Services Digital Network
ISO:	International Standards Organization; publishes computing standards including JPEG and MPEG.
ITU:	International Telecommunications Union; UN body published telecom standards
JPEG:	Joint Photographics Experts Group
Kbps:	Thousands of bits per second.
Latency:	Delays between transmission and reception of stream caused by network, encoding, and decoding.
Lossless:	Codec where no data is lost during encoding and decoding.

Lossy:	Codec where some data is lost during encoding and decoding includes JPEG, MPEG, H.XXX.
Mbps:	Millions of bits per second.
MPEG:	Moving Pictures Experts Group; an ISO standards group that publishes video encoding standards.
MPEG-1:	First of the MPEG video standards, used primarily for video CD and broadcast.
MPEG-2:	subsequent standard to MPEG-1; used for broadcast, DVD; includes Layer 3 audio commonly known as "MP3."
MPEG-4:	Latest in the MPEG family; used for network transmission of video, especially wireless.
NTSC:	National Television System Committee; 525-line analog TV standard used in North America and Japan.
PAL:	Phase Alternate Line; 625-line analog TV standard used in Europe.
Pixel:	Picture Element; the smallest discreet part of a displayed image.
QCIF:	Quarter CIF; 176 X 144 pixels.
RTP:	Real-Time Transport Protocol
RTSP:	Real-Time Streaming Protocol
RVSP:	Resource Reservation Protocol
SQCIF:	Sub-Quarter CIF: 198 X 96 pixels.
TCP:	Transmission Control Protocol
UDP:	User Datagram Protocol

APPENDIX B – VIDEO SERVER VENDOR CUTSHEETS

APPENDIX C – VIDEO SOFTWARE SYSTEM CUTSHEETS